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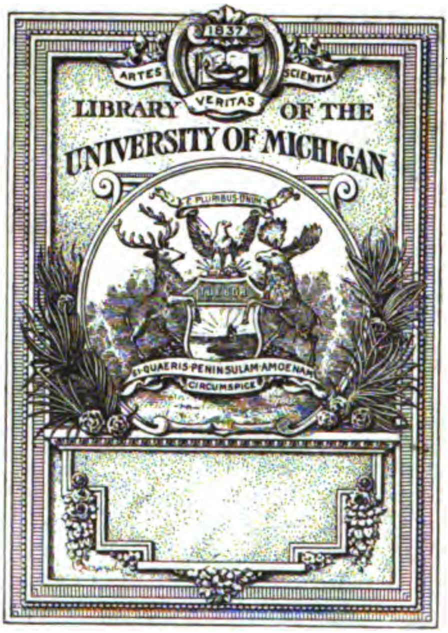
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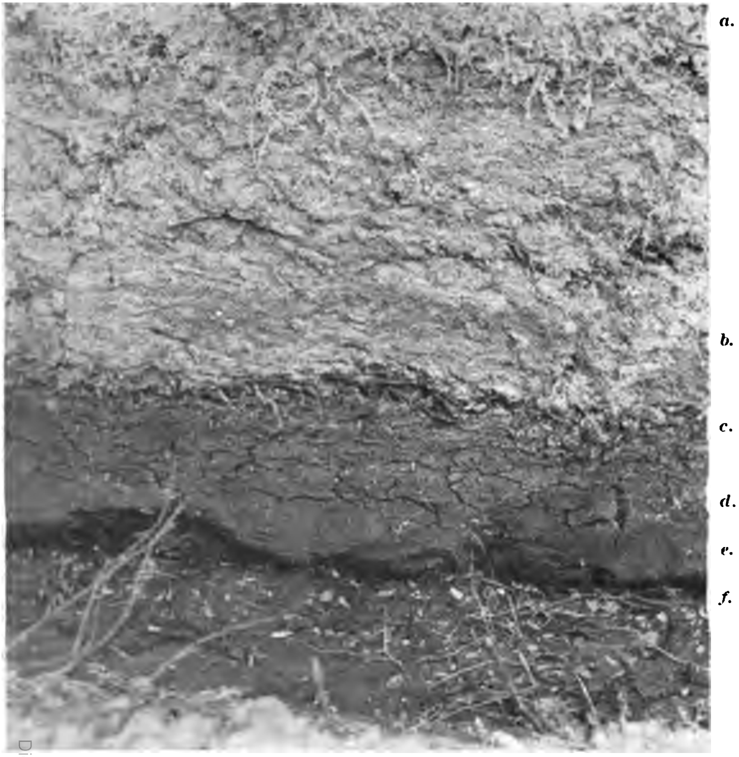
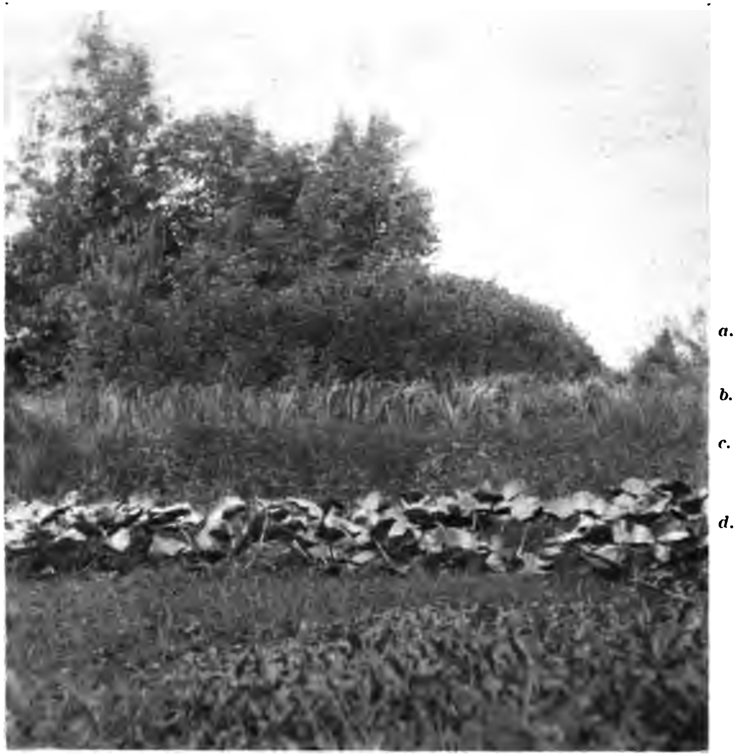


A.
Section of ditch near Vestaburg, showing light Sphagnum peat over dark peat.

Legend A.
- (*a.*) Living Sphagnum.
- (*b.*) Sphagnum peat.
- (*c.*) Shrub remains.
- (*d.*) Sedge rootstocks.
- (*e.*) Pond Lily rootstocks.
- (*f.*) Laminated peat.



B.
View of surface near ditch, showing corresponding vegetative zones.

Legend B.
- (*a.*) Shrub zone.
- (*b.*) Grass zone.
- (*c.*) Sedge zone.
- (*d.*) Pond Lily zone.

PEAT

ESSAYS ON ITS

ORIGIN, USES AND DISTRIBUTION IN MICHIGAN

BY

CHARLES A. DAVIS

Published by the State Board of Geological Survey, as a part of the report for 1906, and
a contribution also to the Biological Survey of the State, author-
ized by Act 250, Session 1905.

LANSING, MICHIGAN
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1907

LETTER OF TRANSMITTAL.

Office of the State Geologist,
Lansing, Michigan, November 20, 1906.

To the Honorable, the Board of Geological Survey of the State of Michigan:

Hon. Fred M. Warner, President.
Hon. W. J. McKone.
Hon. Patrick H. Kelley, Secretary.

Gentlemen:—I herewith transmit to you for publication in your report for 1906, a series of papers on peat, prepared by C. A. Davis, of Ann Arbor. They are the fruit of a happy marriage of botany with geology, and should not be separated. While on the one hand they are an original and important contribution to the botany of peat and the peat producing flora, they are of value in many ways to the geologist, and to any one interested in the promotion of legitimate industry. Information about peat has been too much left to the one-sided investigation of the promoter, who, in his over zeal, may ruin a really desirable development by over estimates of the profits and under estimates of the cost.

Prof. Davis has endeavored to make clear, in the following papers, some of the facts regarding the peat deposits of Michigan which should be of practical value to those who contemplate developing such deposits for commercial purposes.

Some of the more important of these facts are:

That peat deposits are quite variable in structure and origin, but their structure is primarily dependent upon the form of the land surface upon which they are found, and the height of the water above this while they are being formed.

That the most important peat deposits and those most likely to be of commercial value, are found in depressions, or valleys, which have been filled, or partly filled, with peat, through the growth and decay of various groups, or associations, of plants, which succeed each other in a very definite and orderly manner, according to certain laws of plant growth.

That there are many species of plants concerned in peat formation, but of these, the ones growing in the water and a few grass-like plants growing slightly above the average level of the water, are much more important than any others.

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That there usually is no relation between peat and the vegetation growing upon its surface. The character of the vegetation is entirely governed by certain laws of plant growth, and primarily by the level of the water in the deposit. The surface vegetation generally gives no clue to the quality of the peat.

That Sphagnum moss is not an important plant in peat formation in the area under discussion, as it is not present until late in the history of the development of any class of peat deposits.

That certain types of peat deposits are of irregular structure and others are free from irregularity, but only careful study of sections can demonstrate these facts for given deposits.

Very respectfully,
ALFRED C. LANE,
State Geologist.

CONTENTS.

PART I.

THE ECOLOGY OF PEAT FORMATION IN MICHIGAN.

Page
Introduction.......... 105
Chemical composition of vegetable matter.......... 105
Agents of decomposition of vegetable matter.......... 106
Varying rate of action of decomposing agents.......... 106
Description and occurrence of peat.......... 108
Geographical distribution of peat.......... 110
Distribution of peat in Michigan.......... 111
Classification of Michigan peat deposits.......... 114
Peat deposits classified according to the form of land surface upon which they have been formed.......... 115
Classification according to method of development.......... 120
Classification according to surface vegetation.......... 121
Principles underlying the relation of plants to peat deposits.......... 128
The formation of peat in depressions.......... 130
  (a) In shallow depressions.......... 131
  (b) Upon flat areas.......... 134
  (c) In deep depressions, from sides and top.......... 135
Effects of consolidation and raising the surface of the deposit.......... 138
The water plants and sedges in relation to the peat.......... 152
Succession of plants upon the peat after the grounding of the sedge mat.......... 158
Some ecological factors which control this succession.......... 160
Deposits behind dams.......... 167
Conclusion.......... 170
Bibliography.......... 173

PART II.

THE FORMATION, CHARACTER AND DISTRIBUTION OF PEAT BOGS IN THE NORTHERN PENINSULA OF MICHIGAN.

OBJECTS OF THE SURVEY.

Introduction and acknowledgments.......... 183
Itinerary and areas studied.......... 185
Methods of work on peat.......... 187
Types of locality examined.......... 188
General distribution of the plants of Northern Michigan.......... 188
Soil and topography of the region in relation to the plant societies.......... 190
Types of forest.......... 191

THE DRUMLIN REGION PEAT DEPOSITS. VALLEY BOGS, THEIR CHARACTERISTICS. IMPORTANT PLANT ASSOCIATIONS OF THIS TYPE.

Partially filled lakes of this area; ways in which they are filled.......... 195
  Hayward lake.......... 195
  Pond in peat bog at Nathan.......... 198

Page
Completely filled lake or basin near Nathan 201
Algal lake 203
Merryman's lake 210
Bogs near Hermansville 212
  A mature valley bog 212
  A cleared bog 214
Bogs near Faunus 214

PEAT IN THE MORAINAL REGIONS.

Bogs in sand-plain near Vulcan 217
Lake near Menominee river south of Norway 219
Lake Antoine, a large basin beginning to fill 219
Sphagnum bog near Lake Antoine, Iron Mountain 221
Mature valley bog near Granite Bluff 223
Badwater lake, north of Iron Mountain 224
Bogs near Badwater lake 224
Bogs near Twin Falls 226
Lakes near Sagola 227
Bogs and lakes north of Crystal Falls 228
  A mature bog 228
  Camp lake, a partly filled lake 229
  Spring bog near Camp lake 230
Bogs near Amasa 231
  A river-flooded lake 231
  A mature bog 231
Spruce bog at Balsam 232
Lakes and bogs in the sand plains south of Crystal Falls 233
  A rejuvenated sedge bog near Clara lake 233
  Two shallow lakes in the sand plain 233
  Deep lakes near Stager 234
  Mature bogs near Mary lake 236
Bog near Iron river 237
Mature peat bog north of Bessemer 238
Lakes and bogs in the Keweenaw peninsula 240
  Bogs near Winona mine 240
  Lake near Winona mine 241
  Bear lake 243
  Buried peat, on the shore of Lake Superior 243
Lakes near Marquette 245
Lakes and bogs between Newberry and Lake Superior 246
  The Great Swamp 246
  Small lake, T. 47 N., R. 10 W 246
  McLeod's lake 247
  Bog at Stuart's lake 247
  Lakes at Deer Park Life Saving Station 248
  Lakes between Grand Marais and Newberry 248
Bogs near Trout Lake Junction 249

PEAT OF THE SAND DUNES.

Formation of peat in sand dune areas near Lake Superior at Marquette 251
  Buried peat near Marquette 252
Formation of peat in sand dune areas near Lake Michigan at Manistique 254

PEAT IN THE HURON MOUNTAINS.

Types of swamps and bogs 262

GENERAL CONCLUSIONS REGARDING PEAT FORMATION IN THE NORTHERN PENINSULA OF MICH.

Comparison of northern and southern lakes in process of filling 269
  Important types of filling 270
  Factors controlling the width of the mat or marginal zone 271
  Periodicity of growth of the mat 271

THE SPECIES CONCERNED IN PEAT FORMATION.

Page
Relation of Sphagnum to peat formation in the Northern Peninsula.............. 274
Distribution and abundance of peat.. 276

ECONOMIC CONSIDERATIONS.

Necessity of careful prospecting.. 277
Other fuels available.. 278
Peat coke in relation to the iron industry.................................... 278
Agricultural possibilities of the peat bogs................................... 279
Other uses to which peat might be put... 280
List of the common names, and the equivalent scientific names of the plants mentioned in this report.. 281

PART III.

ECONOMICS OF PEAT.

MISCELLANEOUS USES OF PEAT.

Introductory... 289
Uses in agriculture.. 289
  Importance of muck soils in Michigan agriculture......................... 289
  Difficulties in growing crops on muck or peat soils...................... 290
  Methods used in reclaiming swamp lands.................................. 292
  Peat as a fertilizer... 293
  Stable or barnyard litter on farms....................................... 295
  Peat as a disinfectant for farm use...................................... 296
  Peat as stock food... 297
Peat as a deodorizer and disinfectant in towns and cities.................... 297
Destructive distillation of peat.. 299
  Peat coke and by-products.. 299
  Peat gas.. 305
Paper pulp, paper and cardboard... 307
Woven fabrics from peat... 308
Packing material.. 309
Roofing and sheathing paper... 309
Non-conducting packing material... 309
Paving and building blocks.. 310
As a source of electricity.. 310
Peat dye.. 310

PEAT AS FUEL.

Historical development of the peat fuel industry in Europe.................. 311
  In America... 313
  In the United States... 313
  In Canada.. 313
  In Michigan.. 313
Methods of prospecting.. 315
  Prospecting tools.. 316
  Final sampling... 316
  Importance of thoroughly proving a deposit................................ 317
Factors affecting commercial value of deposits................................ 318
  Market and transportation.. 318
  Area and depth... 318
  Physical condition... 319
  Deep bogs with thin stratum of peat with water or marl below.............. 319
  Sampling for other purposes than fuel.................................... 319
  Chemical composition and ash... 319
  Possibilities of draining.. 320
  Character of the surface growth.. 320
  Acidity.. 320

Page
Sources of contamination producing high ash content........ 320
  Importance of ash........ 320
  Flooding by streams........ 321
  Flooding by rain wash........ 321
  Spring and terrace bogs........ 321
  Shore wash in lakes........ 322
  Mineral matter from water........ 322
    In suspension........ 322
    In solution........ 322
      Precipitated by plants........ 322
        (1) Higher plants. (2) Algae........ 322
Relation of deposits of peat to the bottom........ 323
Summary........ 324
  Color........ 324
  Weight........ 324
  Texture........ 325
  Relation of ash to commercial value........ 325
Location and extent of peat beds in Michigan........ 326
Fuel value of peat........ 332
  Compared with other fuels........ 333
  As affected by methods of preparation........ 336
  As affected by cost of preparation........ 342
  Conclusions........ 342

MACHINERY FOR THE PREPARATION OF PEAT FUELS AND PEAT LITTER.

The slayne or slane as used in different countries........ 343
Machinery for making cut peat........ 344
Machines for compressing or condensing peat........ 346
Machines for drying and briquetting peat........ 352
Methods of coking peat........ 357
Machinery for the preparation of peat litter........ 357
Devices for carrying peat from bogs to factory........ 358
Peat factories and peat prospects in Michigan........ 359
Conclusion and acknowledgments........ 361

LIST OF ILLUSTRATIONS.

PLATES.

Page
XIII. A. Section of ditch near Vestaburg showing light colored sphagnum over dark peat.... 93
B. Horizontal view in same bog.... 93
XIV. Beaver dam near Negaunee, photograph by R. H. Pettit.... 166
XV. Beaver meadow near Negaunee, photograph by R. H. Pettit.... 168
XVI. Map of swamp distribution, after Farmer.... 172
XVII. Map of original vegetation of Upper Peninsula.... 182
XVIII. Old White Pine forest near Koss, Menominee county.... 188
XIX. Mature conifer bog near Mansfield, rejuvenated.... 193
XX. Sedge marsh on the margin of a sand plain lake.... 196
XXI. Lake margin at Nathan, Menominee county.... 198
XXII. Border of mature bog near Nathan, Menominee county.... 200
XXIII. Pine "Island," Lake Antoine, near Iron Mountain.... 212
XXIV. North side of lake near Badwater lake.... 216
XXV. Western margin of the same lake as Plate XXIV.... 220
XXVI. Old growth of stunted Black Spruce at Balsam, Iron county.... 228
XXVII. Spruce-Shrub-Sedge bog near Lake Mary.... 236
XXVIII. A. View of peat deposit on rock, Bentley's camp. Photograph by C. Bentley.... 260
B. Black Spruce-Heath Association, Bentley's camp. Photograph by C. Bentley.... 260
XXIX. A peat bog, an old time slane, and an Ames slane.... 288
XXX. Peat fuel.... 300
XXXI. Leavitt peat machinery.... 356

FIGURES.

2. Section of bog, after Shaler.... 127
3. Showing structure of peat bed built up from the bottom.... 135
4. Showing how plants fill depressions from sides and top.... 137
5. Ideal sketch of Grand Trunk track as laid on the bog at Haslett Park.... 154
6. Map of displacement of track.... 155
7. Sketch of track after new grading.... 155
8. Profile at the same point as figure 5.... 156
9. Sketch map of Algal lake, Menominee county.... 204
10. Ideal section of peat deposit of Algal lake.... 209
11. Plant zones in small lake near Merryman's lake.... 211
12. Section through a mature peat deposit near Hermansville.... 213
13. Diagram showing way in which Andromeda and Cassandra build out over the water in a lake near Stager.... 235
14. Section of a bog north of Bessemer.... 239
15. Section of a bluff with buried peat, shore of Lake Superior, two miles east of Portage canal.... 244
16. Buried peat bed near Marquette.... 253
17. Illustrating maintenance of ponds on slopes covered with sand dunes.... 259
18. Peat samplers.... 317
19. Peat cutter after Brosowsky.... 345
20. Plans and section of peat factory inserted facing page.... 347

PART I.

PEAT AND ITS ORIGIN.

THE ECOLOGY OF PEAT FORMATION IN MICHIGAN.

ECOLOGY OF PEAT FORMATION IN MICHIGAN.

Introduction.

While peat has been commonly used for fuel in northern and western Europe from remote antiquity, and its use is still large and apparently increasing in Germany, Holland, Russia, Denmark and Sweden,[1] it has not been brought to the attention of the people of Michigan until recently, that great quantities of this fairly efficient fuel exist within the boundaries of the state, as much as one-seventh of its entire area, or about 5,200,000 acres, being estimated as swamp or muck land,[2] although not all of this is underlain by peat. The prolonged strike of the hard coal miners in 1902-3, followed by the scarcity and high prices of all sorts of fuel, taken in connection with the rapidly disappearing forests of the state, led to the consideration of all possible sources of increasing the available fuel supply, and among these, peat was mentioned and its availability investigated. After some preliminary tests, at several places in the state, plants were projected for the purpose of putting peat into such form that it could be transported cheaply and placed upon the market, in competition with other fuel, especially with coal. A brief preliminary report upon peat in Michigan, prepared by the State Geologist, Mr. Alfred C. Lane, appeared in the Annual Report of the State Geological Survey for 1902, and to the writer was assigned the task of making some more extended investigations into the method of peat formation and accumulation, the causes for its variations in structure and appearance, and its distribution within the state, especially in the Southern Peninsula, and out of these investigations the present paper has developed.

In a discussion having the scope attempted here, certain elementary principles must be laid down in order that the position of the writer may be clear, especially since the paper is intended for the non-technical as well as the technical reader, but such statements will be made as brief as is consistent with clearness.

The Chemical Composition of Vegetable Matter.

All organic matter, whether of animal or vegetable origin, is made up principally of three, or, at most four, chemical elements, of which one only, carbon, is a solid, the others being gases. Besides these three or four important elements, others, including some of the metallic elements, are always present in vegetable matter, but only in small quantity, and are grouped together as ash in the analyses and may be neglected as immaterial in the present paper.

---

[1] Carter, W. E. H., Peat Fuel; Report of Ontario Bureau of Mines, 1903, p. 193.

[2] Towar, J. D., Mich. State Ag. College Ex. Station, Bull. 181, p. 157, 1900.

When uncombined, or only partly combined with oxygen, carbon is the most important fuel element, and all forms of fuel have it as a chief constituent and are good or poor, as they have much or little of this element is available form in them. In vegetable matter, such as wood, the leaves and the stems of plants, carbon is associated with two gases, hydrogen and oxygen, to form, among others, the complex substances, cellulose, or ordinary vegetable fiber ($C_6 H_{10} O_5$) and lignin, or woody fiber ($C_{35} H_{24} O_{20}$). Nitrogen, also a gas, is present in small quantities in certain vegetable substances, associated with the three elements already named.

In both cellulose and lignin, as will be seen from the chemical formulas, the three elements are built into complicated molecules, having many atoms of each, and hence, relatively to the more simple inorganic molecules, unstable and easily decomposed.

Agents of Decomposition of Vegetable Matter.

When allowed to remain exposed to the air, in the presence of moisture, it is well known that most forms of vegetable matter rot, and finally disappear entirely, and such decay has been described as a form of oxidation,[1] similar to, if not identical with, that which occurs when the same sort of material is burned; that is, as a purely chemical process. This process is not, however, directly due to the action of the air, or any of its gaseous constituents, or to moisture. Perfectly dry vegetable matter will keep indefinitely in the air, as is shown by innumerable articles in common use. In like manner, we find that wood and similar material of vegetable origin will keep for very long periods of time when entirely submerged in water. The decay of vegetable matter is really a series of complicated changes, due to the growth and development of living organisms in the decaying matter. These use part of the material of which the vegetable tissue is composed for their own nourishment and growth, and thus break it down into simpler compounds. The organisms which thus produce decay are mainly plants of simple structure, and often of microscopic size, and when they are not so small, their lack of color, and their intimate association with the tissues in which they grow, render them very inconspicuous. These plants are bacteria and fungi, and are aided in bringing about decomposition by many types of animals.

Like all other plants, these decay-producing forms need both air and moisture in order to grow, and, moreover, the moisture must be present in proper amount, too much water being as detrimental to their growth as too little, and where air is excluded they do not thrive.

Varying Rate of Action of the Decomposing Agents.

When the conditions are favorable for these plants to grow (that is, sufficient moisture, air, and a favorable temperature), they may develop with great rapidity, and bring about quick and complete reduction of vegetable material to simple gaseous compounds, such as carbon dioxid (CO_2), ammonia (NH_3), and water, and the vegetable matter as such, ceases to exist. Thus, in moist woodlands, even the hardest wood soon becomes rotten, then loses its woody structure entirely, and finally vanishes, leaving possibly a trace of dark soil to show that it once existed, but nothing that shows that it was wood. The fallen leaves in the forest last much less time than wood and soon become indistinguishable from the soil of which they become a part.

---

[1] Scott, W. B., Introduction to Geology, 1897, p. 133.

If conditions are less favorable the bacteria and fungi do not thrive, the decay of wood and leaves goes on more slowly and is less complete, so that in wet woods, where the temperature is low, wood and leaves may lie for several or many years with little change, and in dry woods such débris may accumulate until a thick layer is formed, only the lower parts of which are decomposed. If, because of very unfavorable conditions, some kinds of the destructive organisms cannot exist, and others are reduced in numbers, a slow and partial decomposition may take place, in which the more easily broken-down compounds of the vegetable matter disappear, leaving the more resistant ones almost unchanged. In such cases, the original mechanical form of the affected tissues may be entirely lost, while the chemical composition of the larger part of them is only slightly affected, and such changes as do take place go on slowly.

In some cases, where water containing mineral matter, or certain organic matters in solution, is present in large excess, chemical changes not produced by organisms may occur and in such cases it is natural that part of the gaseous elements of the molecules which are undergoing change, being chemically more active than the solid carbon, and more free to move, should separate from the molecule first, and leave the carbon associated with smaller proportions of hydrogen and oxygen.

What Peat Is.

From the foregoing considerations it is apparent that vegetable matter may undergo decomposition under a variety of conditions, dependent upon which the amount of change will vary. Some of these conditions permit the changes to result finally in complete decay, and in nearly complete disappearance of the substances, and others simply allow the process to result in the loss of the more easily changed compounds, and of the gaseous elements, while the greater part of the material retains its original form and mechanical structure.

Peat, when examined with a view to determining its origin, will usually, even to the unaided eye, show vegetable structure, and frequently well-preserved plant remains will be found in it in large quantity. If decay and disintegration have gone so far that the larger plant structures have disappeared, it is still usually possible to identify the vegetable tissue-elements, cells, or parts of cells, by the aid of a compound microscope. It is then clearly demonstrable that peat is vegetable matter which has become partly decomposed. In the process of decay, it has been more or less completely changed chemically, and usually mechanically, but in such a way that it still retains a large part of the carbon, together with more or less of the other more readily dissipated volatile matters which wood and other forms of plant structures contain.

Description of Peat.

When dry, peat is of a color varying from a light yellowish brown to nearly black, and when wet the shades of color are all much deepened, the darker ones appearing quite black. It also varies in texture and structure from a loosely felted, slightly coherent mass of plant remains having low specific gravity, to a compact, structureless material which is relatively heavy, quite plastic and sticky when wet, and which dries into firm, tough masses. There seems to be, in general, a close relationship between the color and texture of different types of peat, the lighter colored types being coarser in texture, and approaching ordinary dried vegetable litter in appearance, while the darker sorts are nearly as structureless as clay. In most deposits of peat which have been undisturbed by human agencies, there is a progressive change in color from light to darker shades, and, in texture, from coarse and loose, to fine and compact, as the bed is cut through from top to bottom. The chemical composition of the different types of peat also varies, as shown by the following analyses cited by Ries[1] from Johnson.[2]

Material.	Analyst.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Sphagnum,	Websky	49.88	6.54	42.42	1.16
Peat, porous, light brown, Sphagnum.	"	50.86	5.8	42.57	.77
Peat, porous, red brown,	Jaeckel	53.51	5.9	40.59	
Peat, heavy brown,	"	56.43	5.32	38 25	
Peat, dark red brown, well decomposed,	Websky	59.47	6.52	31.51	2.51
Peat, black, very dense and hard,	"	59.7	5.7	33.04	1.56
Peat, black, heavy, } Best for fuel,	"	59.71	5.27	32.07	2.59
Peat, brown, heavy, }	"	62.54	6.81	29.24	1.41

From these analyses, which neglect the ash, it is apparent that in the denser and darker peats there is a larger amount of carbon and a smaller amount of oxygen than in Sphagnum, or in the more porous, lighter colored types, amounting to from 8 to 12 per cent increase in carbon and from 8 to 12 per cent decrease in oxygen.

Muck is the name given to dark colored, thoroughly decomposed peats in which there is a considerable mixture of mineral matter, but as this is very variable in quantity, there is no sharp distinction to be made between peat and muck, as all peat contains some mineral matter, which appears as ash when the peat is burned.

In the natural state, peat is always saturated, or nearly saturated, with water, except in the uppermost layers, and in very dry times.

Occurrence.

Peat usually occurs upon gentle slopes, flat areas, and in more or less shallow depressions in the earth's surface, which have either no direct drainage, or are poorly drained, so that the surface is always wet or covered by water. In these places are formed eventually the accumulations known as "bogs," "marshes," and "swamps." Names for the same forms of deposit are "morass,"[3] "moor"[4] and fen, but these, in America, are not common terms, or are not in use, and do not need discussion. The first three, however, are used so interchangeably that it may be well to define them in the sense in which they are used in this paper. The writer has not adopted the use of the German word "moor" as a substitute for "bog," because the English word "moor" is already in use with a fairly constant meaning, namely, to designate a broad, flat upland with light soil, covered with grasses and shrubs, and while such moors may be more or less covered with peat in some cases, they are not generally peat deposits. A bog is an area of wet, porous land, on which the soil is made up principally of decayed and decaying vegetable matter, so loosely consolidated, and containing so much water, that the surface shakes and trembles as one walks over it. The vegetation upon the surface is variable, but it is characteristically either some species of moss or of sedge, or grass, or a combination of two or more of these with shrubs and even small trees. This is in part identical with Cowles'[1] undrained swamp, and is well illustrated by many examples in various parts of the Southern Peninsula, of which Mud Lake, in sections 1 and 12, T. 1 S., R. 5 E., about one and one-half miles west and nine miles north of Ann Arbor, the south and east border of Half Moon Lake, in Gratiot county, in sections 5 and 6, T. 12 N., R. 4 W., and a bog near Hobart Station, 5 miles southwest of Cadillac, on sections 30 and 31, T. 21 N., R. 9 W., and the region adjacent are types.

---

[1] Ries, H., 21st Report of the New York State Geologist, 1901, pp. r. 58, 59.

[2] Johnson, Peat and its uses, p. 24.

[3] Shaler, N. S., Fresh-water Morasses of the United States, U S. G. S. 10th An. Report, p. 261.

[4] Coulter, J. M. Plants, Chicago, 1900, p. 187.

A marsh has a firm soil; that is, not easily shaken when walked upon, although it may be soft and very wet, even submerged, and the vegetation upon it is principally grass-like; that is, with long narrow leaves, and weak, short-lived aerial stems. Shrubs may occur upon marshes, and where they are present not infrequently form thickets. The development of typical marshes is much greater than that of bogs as defined above, and much larger areas of marsh are to be found in more or less accessible places. In the southern part of the state, the Detroit and St. Clair rivers, the shores of Saginaw bay, in Akron and Wisner townships, Tuscola county, and inland, a considerable part of James township, Saginaw county (T. 11 N., R. 3 E.), several sections on the Ann Arbor R. R., in T. 9 N., R. I W., and considerable areas of the shores of the lakes about Lakeland in Livingston county, are examples. In marshes of this character the depth of peat may be slight or considerable.

A swamp, according to the writer's usage in this paper, has trees and shrubby plants as the most important part of the vegetation, the soil being, as in the case of the marsh, firm, but wet, even, at times, to flooding. The swamps are even more common than marshes and great areas of the state were formerly covered by this type of formation, which have long since been cleared, drained, and converted into agricultural land. One of the most extensive swamps seen in the Southern Peninsula of Michigan, by the writer, is located due west from West Branch, in Roscommon county, and is traversed by a state road to Houghton Lake. The timber in this tract is largely Tamarack, *Larix laricina* (DuRoi) Koch, and Arbor Vitæ, *Thuja occidentalis* L. Smaller swamp areas in nearly natural condition exist in many parts of the southern tiers of counties, notably at various points along the rivers, and around many of the lakes which occur here.

These types all intergrade more or less among themselves, and with swamps and marshes in which the soil is not of vegetable origin; hence no absolutely sharp differentiation can be made unless a rather elaborate set of compounds be devised. Not infrequently the three types may exist in the same basin and, as at Mud Lake, referred to above, it is possible to pass from one type to the other in crossing the deposit around the lake, and in many other cases around lakes the same relationship exists, the bog lying next the lake, the marsh next inshore, and the swamps extending back often to the high ground which may have formed the shores of the lakes originally. This, as will be seen later, is a perfectly normal arrangement, and one easily explained.

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[1] Cowles, H. C., The Physiographic Ecology of Chicago and vicinity, Bot. Gaz. XXXI, 3, pp. 147-154.

Of the three terms, "bog" is the one most often used in describing deposits of peat, but this is perhaps an inheritance from English and other European literature on the subject, for in northern Europe the peat is very often found in bogs, as described above.

Since peat is formed on undrained areas or in depressions, the extent and depth of a given deposit is generally determined by that of the plain or basin in which it lies, but as pointed out by Shaler,[1] it is possible for the area of peat formation to be extended outward from a center under certain climatic conditions by the encroachment of certain species of plants which may be good peat formers upon the area occupied by those which are not large contributors of vegetable matter. This has not been noted by the writer in his studies in Southern Michigan. Since, as will be shown later, the conditions for rapid accumulations of peat are more favorable in shallow basins than in deep, and in those of limited extent than in large, there are many more small deposits than large ones, and it is rare to find accumulations of more than forty or fifty feet in depth, although deeper ones are known to exist.

Geographical Distribution of Peat.

The conditions favoring the formation of peat are such that it is found most commonly in moist and cool or cold parts of the earth, hence in northern Asia, Europe and North America it occurs in great abundance, but that it is not lacking in the southern hemisphere is shown by the account of the extensive deposits of this substance on the islands on the southern coast of South America by Charles Darwin,[2] who states that the climate of the southern part of America appears particularly favorable to its production. Ries[3] states that, "Peat deposits are found chiefly in north temperate climates, especially in moist ones. Many thousand acres of the North German plain are underlain by deposits of peat, while in Ireland alone it is estimated that there are 1,576,000 acres of flat bog, and 1,254,000 acres of mountain bog. Russia is said to have 67,000 square miles of peat land, and there are several million acres in Norway and Sweden, while extensive deposits are not lacking in France and Holland. Peat bogs are common in New York, Pennsylvania, Michigan, Wisconsin, and Minnesota."

Le Conte[4] quotes estimates by Dana, that Massachusetts has 15 billions of cubic feet of peat and also states that California has large areas of imperfect peat in the "tule lands" about the mouth of the San Joaquin river and elsewhere and that extensive swamps exist in Virginia, and North Carolina. In Europe 1-10 of the whole surface of Ireland, large parts of Scotland, England and France are covered with peat. The bog of the Shannon river is fifty miles long and three miles wide, that of the Loire in France is 150 miles around. In Canada, according to Carter,[1] peat bogs are numerous, and, in extent and wideness of distribution are probably not exceeded by those of any other country of equal area. North of the height of land, say 50 miles south of James Bay, peat muskeg covers the face of the earth for hundreds, perhaps thousands of square miles, and stretches northward along the westerly shores of Hudson's Bay. In the United States it is estimated that there are 75,000,000 acres, or 120,000 square miles of swamp land.

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[1] Op. cit., pp. 284-285.
[2] C. Darwin, Naturalist's Voyage around the world; 1888, pp. 287-288.
[3] Op. cit. p. 65.
[4] Le Conte, J., Elements of Geology. 1896. p. 147.

This distribution of peat deposits seems to be due in large measure to a combination of factors, among which are abundant precipitation, regularly distributed throughout the year, slow percolation and slight evaporation from the surface, and small run off of the surface water, because of poor drainage. There must also be a mild season sufficiently long to permit plants to grow with vigor and abundance enough to furnish accumulations of débris from which peat may develop. These factors are all operative in the cold temperate regions of the continents mentioned above as areas of extensive peat deposition. They are poorly drained, since they have been abandoned recently by the ice of the glacial period, and abound in depressions and broad flat divides, and other plains from which the water is but slowly drained by existing streams. The growing season is long enough so that the vegetation is luxuriant, and in the regions of greatest peat deposition it is cool and moist. The soil temperature is low, which tends to hinder percolation from the upper to the lower levels of the soil by increasing the viscosity of the soil water, while the low average temperature of the air is a check upon evaporation from the soil or from water surfaces, since at low temperatures the air is very readily saturated with moisture. The effect of these factors is to keep the surface of the soil constantly wet, and to permit the water which falls upon it to remain there, and accumulate in all depressions.

Distribution of Peat in Michigan.

Location: Michigan lies between the parallels 41° 45′ and 48° 20′ N. latitude and between 82° 25′ and 90° 34′ W. longitude. It is divided naturally by the Great Lakes into two distinct parts, the Upper or Northern, and the Lower or Southern Peninsulas. The greatest length of the northern portion is from east to west and is 318 miles, the width from 30 to 164 miles. The southern portion has its greatest length from north to south, 277 miles, and its width at the widest part is 259 miles. The total area of the state is 58,915 square miles, and the coast line is over 1,600 miles in length.

Since the studies from which conclusions have been drawn in the present paper were made in the Southern Peninsula, only that part of Michigan will be considered in the following brief discussion of the climate and physiography.

The fullest account of the climate of the state is by the late Prof. A.

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[1] Carter, W., E. H., "Peat Fuel; Its Manufacture and Use," Report of Ontario Bureau of Mines, 1903, p. 202.

Winchell[1] which still is, in general, correct in its conclusions, although many additional data have been collected since its publication.

Precipitation: Lane[2] gives the average precipitation for this portion of the state as some 32 inches, and in the rainfall maps of climate charts of the United States[3] the Lower Peninsula lies in the region having between 30 and 40 inches normal precipitation with a small area about Little Traverse Bay having over 40 inches.

The same series of charts show that the precipitation is between 6 and 9 inches in the first quarter of the year, January to March; between 9 and 12 inches for the second and third quarters; and between 6 and 9 inches for the fourth quarter. The period included in these charts is from 1870 to 1896.

The following table cited by Lane[4] from Winchell shows substantially the same thing regarding the distribution of the precipitation during the year:

Distribution of Precipitation in Michigan by Seasons.

Season.	Upper Peninsula.	Lower Peninsula.	The State.
Spring	19%	25.8%	23.8%
Summer	27	28.7	28.3
Autumn	28.8	27.3	27.7
Winter	22	19.1	20

These data make it appear that the season of greatest rainfall is the summer and fall, and as this coincides with the season of greatest heat and consequent evaporation, it is evident that this distribution of rainfall is an important aid in the peat formation[5] and in the warmer parts of the state, may be the primary factor, since it prevents the great drying out of the soil moisture which would take place if seasons of long drought occurred annually.

The rainfall is not evenly and uniformly distributed over the Southern Peninsula but in the southern part, especially the southwestern, is an area of greater precipitation than occurs further north, and the valleys of the Saginaw tributaries have less to a marked degree than is found elsewhere, except in small areas. The western side of the Southern Peninsula has a larger rainfall than the eastern, except a narrow strip from the mouth of Saginaw Bay northward. The differences in the total amount of rainfall are not however large, and taking into account differences in temperature, soil and surface configuration, it is probable that there are few areas of the same size in the United States more evenly watered than that under discussion.

Temperature: The average annual temperature of Southern Michigan varies nearly 10 degrees in going from the southern to the northern ends of the peninsula, and the same may be said of the average maximum and average minimum temperatures, but the isotherms do not run uniformly at right angles with the north and south axis of the state but are variously curved[1] showing that the temperature is profoundly influenced and modified, (1) by the presence of the great lakes on three sides of it, (2) by the great land mass to the south and the southwest, (3) by the high lands in the northern part of the interior of the peninsula. Lake Michigan is especially important in its effects, modifying both the maximum and minimum temperatures very decidedly and as a result of this the climate is more even and milder than that of the region in the same latitude west of the lake. Yet the annual range of temperature is about 116° F. The range of the average mean temperature of the portion of the state under consideration is from 49° at the southern and southwestern parts to 41° in the Straits of Mackinaw, the lines of equal temperature bending northward in the western and southeastern parts, and southward in the high areas in the region northwest and southeast of Saginaw Bay. That is, the western and southeastern parts are warmer and the highlands cooler than those immediately adjacent to them.

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[1] Winchell, A., in Tackabury's Atlas of the State of Michigan, ed. by H. F. Walling. 1st. ed. 1873, 2nd. ed. 1884. Proceedings Am. Assoc. Adv. Sci., Troy meeting, 1870.

[2] Lane, A. C., Water Resources of the Lower Peninsula of Michigan, Water Supply and Irrigation Papers, U. S. G. S., No. 30, 1899.

[3] Climate Charts of the U. S. Weather Bureau, Washington, D. C., 1900. See also Jefferson Report Mich. Acad. Sci., VIII., 1906, and Leverett, F., Flowing wells and Municipal Water Supplies of the Southern Peninsula of Michigan, W. S. & I, Paper 183 U. S. G. S., 1907, p. 10.

[4] Op. cit. p. 49.

[5] Shaler, op. cit. p. 263.

Sunshine: The amount of direct sunshine a region receives is important in a discussion of the vegetation of that region, and the following has been compiled from the maps referred to above.[2] The Southern Peninsula receives, with Wisconsin, part of Illinois, Indiana and Ohio, parts of Pennsylvania and New York, and a portion of New England, between 40% and 50% of sunshine during the year, compared with less than 40% in the Northern Peninsula and more than 70% in the arid region of Arizona and adjacent territory.

During January this sinks to less than 20% in a considerable portion of the western part of the peninsula and is only above 40% in the southeastern part. The area below 20% is the only one in the United States. In July, on the other hand, a very considerable part of the peninsula has over 60% of sunshine, the area extending across Indiana into northern Illinois to the Mississippi, and constituting the only area with so high a total of sunshine east of that river. The rest of the Southern Peninsula has between 50% and 60%. The effect of this relatively large amount of sunshine, during the growing season should be to increase the development of vegetation and to promote its vigorous growth, as well as cause a relatively high range in temperature.

It is thus evident that the Southern Peninsula of Michigan has a sufficiently mild and moist climate to produce abundant plant growth, and that the rainfall is so evenly distributed that no long periods of excessive drought normally occur, but on the other hand, the periods of greatest heat are also times of largest precipitation. The differences between the average temperature of the southern and northern parts are large enough to make a marked difference in the humidity of the climate, if the amount of precipitation is approximately the same, because the air of the cooler region will be constantly more near the saturation point. In this part of the state, also, the periods of greatest heat are shorter and less frequent than in the southern portion, which fact is important in considering evaporation effects upon vegetation and moist or wet surfaces. That is, in the northern part of the Southern

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[1] See Lane, op. cit. pp. 49-53.
[2] U. S. Weather Bureau. Op. cit.

Peninsula, because of the differences in temperature alone, more of the land surface will be available for the formation of peat than in the southern part of the same area, because the drying effects of highly heated air are absent there. The efficiency of this agency is relatively greater for the higher temperatures than for lower ones, since the capacity of the air to take up moisture increases more rapidly above 50° F. than it does below it.

Physical Features: To these climatic conditions which are, on the whole, favorable to the abundant formation of peat, are added certain physical surface features which are also very favorable. Shaler[1] says, "In the conditions which determine the formation of swamps, the shape of the land is generally of most importance." The Southern Peninsula of Michigan is, geologically speaking, new land, recently exposed to the erosive agencies which have not yet had time to develop a complete drainage system. Because of this, there are great numbers of deep hollows, slight depressions and flat areas, in and upon which water accumulates and from which it drains away very slowly, or not at all, forming lakes. Moreover, the agencies which shaped a great part of the surface of Michigan, were such that they left it exceptionally rough, after entirely obliterating the older surface and its systems of drainage, at so recent a time that the new drainage is still in an undeveloped stage. In traveling over the Southern Peninsula one is constantly impressed by the facts that about its borders, for a varying distance from the Great Lakes, the country is quite flat and free from either marked elevations or depressions. Proceeding inland however, the character of the surface changes and often abruptly, becoming rolling, the plain giving place to a series of ridges and hollows, which seem distributed over the land without order or plan. Often between areas of such rolling country will be found broad plains and valleys, which, though relatively flat, are not smooth, but contain frequent depressions in which are found lakes and marshes. The broader plains have a somewhat different geological history from the interior rolling country, but it is sufficient to say that in the marginal plains, while rarely considerable deposits of peat are accumulated, in general such accumulations are shallow and not of commercial extent. In the rough and rolling areas, however, as has been pointed out above, there are many undrained depressions and places where water stands above the land surface permanently, and in this territory, the region of moraines, gravel and till plains, left by the ice of the last glacial period, there are very numerous deposits of peat, many of which are extensive enough to warrant commercial development, and when all the available deposits, large and small, which are to be found in this region are taken into account, they represent an enormous amount of stored-up fuel.

Classification of Michigan Peat Deposits.

Various methods of classification for swamps and peat accumulations have been proposed, and more or less satisfactory schemes for grouping them may be made.

Shaler[2] considering all inundated lands, uses a system based upon, first, the kind of water by which the land was covered, fresh or salt, and then under fresh water swamps, considers the source of the water, whether from rivers, lakes, etc.

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[1] Shaler, N. S., Op. cit. p. 263.
[2] Shaler, N. S., Op. cit. p. 264.

Schimper[1] under the paragraph "moors," states that rich formation of peat on wet soils leads to the production of moors, which occupy very large areas, especially in the cool and moist districts of the cold temperate belt, and classifies them according as they have or have not a limey substratum as "meadow-moors" rich in lime, and "high-moors" poor in lime, with the center built up higher than the margins, hence the name. The same nomenclature was adopted by Fisher,[2] Fruh,[3] Koller[4] and others, and is evidently the ordinary usage in Germany since Eiselen[5] says that, "in East Friesland, Holland, the Holstein region, etc., they usually divide peaty areas into the so-called high and meadow moors."

A very casual study of peat bodies will convince any careful observer that not all of them have been formed in the same way, and a little consideration of the possibilities of each formation will make it apparent that there may be a number of possible methods by which such accumulations have come about. For convenience of discussion the writer has grouped the peat deposits of Michigan in several ways, taking as a basis of the classification, various points of view and elaborating each under a separate head.

Peat Deposits Classified According to the Form of Land Surface Upon Which They Have Been Formed.

This seems the most fundamental basis for a scheme of classification, and hence is considered first. Peat is formed over:

A. Depressed surfaces or hollows.
B. Surfaces not hollowed out.

Class (A) may be subdivided more or less minutely, but of easily recognizable forms of closed depressions, the following are most worthy of consideration:

1. Lake basins of the "tarn" type.
2. Shallow lake basins of the ordinary type.
3. Hollows not permanently filled with water.
4. Hollows in sand dunes.
5. Hollows formed by dams.
    a. Dams formed by differential uplift or tilting.
    b. Dams formed by hard rock outcrops.
    c. Dams formed by glacial ice, morainal dams.
    d. Dams formed by wave, wind, and ice action along the shores of the lakes.
    e. Dams formed by rivers and streams at flood time, cutting off portions of their flood plains, or of their channels.
    f. Driftwood dams in sluggish streams.
    g. Beaver dams.

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[1] Schimper, A. F. W., Plant Geography upon a Physiological Basis. Trans. by Fisher. 1903. p. 657.

[2] Fisher, Chem. Technol. der Brennstoffe. 1897.

[3] Fruh, I., Torf und Dopplerit, Zurich, 1883.

[4] Koller, T., Die Torf Industrie, Wien, 1898.

[5] Eiselen, J. C., Handbuch oder............Anleitung zur............Kentniss des Torf wesens, Berlin, 1802.

Class (B) may also be subdivided into:

1. Poorly drained till plains.
2. Broad divides.
3. The floors of glacial drainage valleys.
4. Lake and stream terraces.
5. Deltas of streams.
6. Slopes over which seepage spring waters flow.
7. Northern bogs, in which peat forms on slopes, i. e. "climbing bogs."

Among the thousands of small lakes in the Southern Peninsula, there are several well-marked types, among which two, tarns and ordinary lakes, from their frequency, may be cited. These are formed in hollows in glacial moraines, or in the depressions which occur so frequently in the gravel plains, which mark the lines of drainage from the front of the glacial ice. The term "tarn" is applied to any of these small lakes in which there is no visible inlet, and such lakes as the "Sister Lakes" a short distance west of Ann Arbor, Whitmore Lake, 10 miles north of that city, and Bass and Rock Lakes near Vestaburg, Montcalm county, are examples of this class. Whitmore Lake is also an example of the type filling a depression in a plain, as are Rock and Bass Lakes. Many of the lakes in Lyndon Tp., T. 1 S., R. 3 E., are excellent examples of morainal lakes, and several of these, like Cedar Lake, in section 9, are tarns as well. Lakes of the ordinary type, with well marked inlets and outlets are so numerous as to need no illustration, since they occur so frequently that hardly a portion of the Southern Peninsula, except the region about Saginaw Bay, is without them.

There are abundant illustrations also of the third class of depressions, those not filled permanently with water, especially in the morainal parts of the state, which, while they have considerable water in them at times are not continuously occupied by lakes and may be termed intermittent lakes in some cases, while in others, they may represent filled lakes, or may be merely marshy. Peat accumulates in them, in some cases, and in others does not, the general rule seeming to be that in the southern part of the state, if shallow, they contain little peat, while north, they are usually partly filled with peat, whether shallow or deep.

The sand dune regions of the Southern Peninsula are chiefly in the immediate vicinity of the Great Lakes, and here between dunes will often be found swampy areas, formed apparently by the fact that the dunes rest upon a clay substratum, upon which the water which soaks into the sand of the dunes, accumulates in sufficient quantities to induce bog, swamp or marsh conditions. The shores of Lake Michigan, where not too high, the region around Saginaw Bay, and of Lake Huron north of that Bay, give numerous examples of this type of depression, while in Vassar township, Tuscola county, may be found occasionally a swamp which has developed in an inland dune region.

The types of basins formed by dams are not always easily distinguished from other depressions, but frequently the dam itself is still easily identifiable, and as the depressions were in many cases originally stream valleys they are often long, and narrow in proportion to their length. The long narrow lakes on the west shore of the Southern Peninsula are, many of them, such stream valleys according to Lane,[1] which have been sunk by differential uplift and later closed by bars thrown across the mouth of the valley by wind and wave action. In a region so generally covered by glacial moraines as the higher parts of the Southern Peninsula it would seem easy to point to moraina dams in numbers, but relatively few are known to the writer. Such a dam crossed the Huron river valley at Ann Arbor at an early stage in the retreat of the Maumee Lobe of the ice sheet to the Lake Erie basin, but it was apparently a very temporary affair, and was soon washed out, and this is apparently the fate of most of such dams to stream valleys, for we find not infrequently that streams have been crossed by moraines which at one time converted their valleys into temporary lake basins. Such a dam held back the waters of the Cass river near Vassar for a time, and the Pine river near St. Louis, and also near Alma, was evidently dammed by small moraines. The height of these dams and their looseness of texture was usually unfavorable to their permanence, for as soon as the water began to run over them they rapidly washed out.

Much more permanent are the barriers, which are built by wave and current action and ice shove in the winter, across the mouths of indentations on the shores of the larger lakes, and which tend to straighten the shore line by cutting off the bays and making them into independent basins. Almost every lake which had originally any irregularities in its shore line shows some such cut off bay. The best illustrations of dams of this type may be found upon the west shore of the state, where wind, waves and current action are all working together to straighten the shore line, and such lakes as Pine Lake near Charlevoix and Intermediate and Torch Lakes on the east side of Grand Traverse Bay and a large number of others show how efficient these dams are.

An excellent example of this type of lake on the eastern side of the state, is Tobico Lake, in Bay county, a short distance north of West Bay City, where the long current-formed sand spit has cut off from the main body of water, what was until recently a bay. Here also may be seen, a short distance to the west of the present Tobico Lake, and at higher levels, two swamps, formed by the filling of lakes, which were cut off in identical fashion from the main bay during the time when the lakes which preceded Lake Huron covered the land. Tobico Lake is shallow and supports an abundant growth of aquatic plants, and is apparently filling rapidly.

These larger examples are cited because they are so conspicuous, but Littlefield Lake in northern Isabella county, T. 16 N., R. 5 W., has six basins, which have been cut off from the main one, in this case by marl, which has closed up mouths of what were formerly bays. The shore of Saginaw Bay, especially on the east side, has many small, shallow ponds just behind the present shore line, which have been made by the sand ridges heaped up by wind and wave action.

The basins formed by stream action differ in shape and are usually, in Michigan at least, of smaller size than those formed by the agencies just mentioned. They are of two types, the marginal and the "ox-bow." The marginal type is usually developed on the shoreward edge of the flood plain of the stream valley, by the elevation of the bottom of the existing channel of the stream by depositions during seasons of high water. This gradually raises the part of the flood plain in which the stream runs, and leaves the remoter margins lower, so that when the banks overflow the water finds its way to those lower places and remains there, or finds its way slowly to the stream lower down in its course. Most streams with a wide valley and rather sluggish current show ponds and lakes caused by this form of dam in some parts of their course. Maple river, a tributary to the Grand, the Saginaw river, the Pine river, near Alma, and many other streams are examples showing this form of dam. The type of depression formed by the changes which streams make in their channels during times of flood is best illustrated by the "ox-bow" lakes, but these are by no means the only forms which occur. Streams in the lower and flatter parts of their courses, where their valleys are wide and the material easily eroded, are most likely to furnish illustrations of this form of dam. The streams in this part of their valleys are likely to meander widely and make very tortuous channels for themselves, and in flood times, when the current increases in velocity, and the amount of water is so great that the streams are out of their banks, they cut new channels, straighter and more direct, and close up, in part at least, the old ones, leaving them as elongated depressions of greater or less extent, which are usually wholly or partly filled with water. The Huron river below Ypsilanti, and in fact the greater number of the streams flowing in broad flat valleys throughout the state, afford examples of cut off channels and bends, so that no student of the subject need go far to seek illustrations.

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[1] Op. cit. p. 65.

In early times in the Southern Peninsula the streams were often blocked for considerable distances with dams of drift wood, the trunks of trees, washed out from along the banks by freshets, and by the undermining of the banks by shifting currents during the ordinary stages of water. These were usually cleared out of streams as soon as lumbering began, and, except in the wilder and more inaccessible parts of the state, will not be allowed to accumulate again, but the following account of such dams by Desor[1] is interesting and shows how extensive such obstructions formerly were. "We had sailed a day and a half on the principal branch of the Manistique, when we were stopped by an accumulation of tree trunks, forming an obstacle across the river. The rafts, which the Canadians called 'embarras,' are by no means rare in the forest, wherever the gradient of the river is slight. A tree trunk uprooted by the current, and dragged along by the river catches on the side of a meander; if the current does not dislodge it, a second trunk coming along is stopped, others come along and their branches interlacing, they end by forming a barrier, which increases indefinitely. There are some of these barriers which have a considerable area and are very old, since they are often found covered with bushes which have taken root upon the floating trunks. The one we encountered here was not of this kind; it was evidently of recent formation, because it was not more than a dozen fathoms in width. The tree trunks were dry and mainly of the Arbor Vitae."

Another of these obstructions in the same stream is described as several hundred fathoms long and very old, covered by shrubs, among others, the raspberry, which grew "as parasites" on the half rotten trunks of the birches and spruces.

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[1] Desor, E., La Foret Vierge, pp. 28-30, Paris, 1879.

It is not to be questioned that such obstructions in streams did much to hold the water back and create marsh and swamp conditions for considerable distances above them.

Of beaver dams little need be said here, since they are discussed at length in another place, except to point out that the extensive deposit of peat at Capac, seems, in part at least, to have been formed in the ponds created by beavers, since their dams were cut through in developing the drainage system of the deposit, and that the remains of the animals and their dams are frequently found in draining swamps and marshes in the central part of the state.

Types of flat areas belonging to class (B) are widely distributed over the Southern Peninsula and only single instances need be cited to show the characteristics of each. The "till plain" is a nearly level area which probably is the ground moraine of a portion of the glacial ice sheet which melted back at a uniform rate faster than the ice advanced, so that no morainal ridges were formed. Such a plain of rather small extent is found in Washtenaw county north of Ann Arbor. The soil is usually bouldery clay and sufficiently impermeable so that the water stands upon the more level parts of the surface, a part of the time at least, thus tending to cause the development of swamps.

The broad flat divide between the tributaries of different drainage systems is a well marked character of young topography, and is frequently found in the Southern Peninsula, in the higher parts especially. Many of these divides are parts of till plains, and are swampy for the same reason that the plains are. The extensive swamp areas between the Pine river and the Maple river in Gratiot county may be considered as examples of this form of land surface.

By glacial drainage valleys are meant those in which the water from the front of the melting ice sheet flowed away to some lake or to the sea; or in some cases they are undoubtedly the temporary outlets of the great lakes which accumulated for a time between the front of the ice sheet and the high land from which it had recently retreated. These valleys are sometimes of great length, and of considerable width, and may or may not be occupied by streams at the present time. Such a valley is usually very flat in the bottom, and where it is not too sandy or gravelly, may become swampy. The series of marshes and swamps extending southward from Huron county to Imlay City and thence southwestward, is such a channel, while the well known celery swamp south of Ann Arbor and those about Kalamazoo are other examples.

Lake and stream terraces are often nearly flat and because of being covered by impervious clays do not quickly absorb rain water, or that which flows over them from higher levels. The wet shores of Saginaw Bay, the well marked marshy areas about the western end of Lake Erie, and the swamps and marshes upon the terraces of such streams as the Saginaw, the Maple and Huron rivers may be taken as typical of these forms of plains.

Streams, besides forming dams along their courses are continually depositing material at their mouths by which they build up a more or less extensive plain of wet soil to the level of the body of water into which they run. These plains are not usually of great extent, but may develop until they fill large areas of the lakes into which they are built. The delta of the St. Clair river in Lake St. Clair described by J. Leon Cole,[1] and that of the Saginaw river are two of the extensive deltas easily accessible and typical of this form of plain, but in nearly every lake which has a stream flowing into it a more or less extensive delta may be found, and upon these it will be seen that there are very favorable conditions for marsh and swamp development.

In many places in the Southern Peninsula, clay or compact till slopes have at their tops, or superimposed upon them, sand or gravel beds, through which the water which falls as rain percolates until it reaches the clay. This it follows until it reaches the expanse of clay and running over the slopes forms a favorable place for the development of peat. Such slopes with bogs upon them occur at Ortonville in Oakland county, in the valley of Huron river, north of Ann Arbor, and at a short distance west of Chelsea, near the line of the electric railway, and in many similar places.

The northern or climbing bog has not been observed in the area studied, but the type may occur in the extreme northern end of the peninsula and has been reported from the Northern Peninsula by Shaler and others.[2]

Classification According to Method of Development.

A second method of classification of peat deposits may be based upon the way in which the deposit was developed, whether from the bottom, or the sides and top, and here again at least two main types are to be distinguished.

(C) Those built up by successive generations of plants, starting from what is now the bottom of the peat.

(D) Those which have been formed by growth at the sides, or at the top of the basin, or both.

Peat deposits of type (C) occur invariably in the shallower depressions, and upon slopes and plains, and since the depth of the water in which even aquatic plants will grow is limited to a few feet, it is evident that no deposit of peat of this kind can be more than this depth, unless from time to time the water level is raised, as the deposit is built up, or it is formed by floating aquatic plants of the higher types, or by algae.

(D) For the same reason it is clear that the filling of deep lakes with peat, so that twenty, thirty or even fifty or more feet of peat may be formed, can only take place in relatively few ways, such as: (1) The washing of dead and decaying vegetation from the shores into deeper parts of the lake basin.

(2) The drifting in of such matter from the tributary streams.

(3) Vegetation may grow out from the shores to form floating mats, which finally extend themselves to cover the entire water surface.

It is probable that it not infrequently happens that there may be filling from the sides, until the water has become shallow enough to enable water plants to attach themselves to the bottom thus formed, and from this time on, the building up from the bottom begins, although the development of peat from the remains of submerged aquatic plants must be very slow, because these contain such small amounts of vegetable matter relative to the semi-aquatic and land plants.

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[1] Geological Survey of Michigan, Vol. IX., Part I.

[2] See also Part II of this report.

(4) In rather rare instances in the southern, and more frequently in the northern part, in small, quiet, sheltered bodies of water, floating, rootless species of plants may develop in sufficiently large numbers at and near the surface to become important factors in the work of filling the deeper parts.

Classification According to Surface Vegetation.

Still a third system of classification is frequently adopted by prospectors for peat, by botanists, and others, which, while it is purely superficial, would, in general, probably be considered as the most natural. This is based upon the kinds of plants growing upon the surface of the deposit, and the inference, which has led to much misapprehension in this respect, is that the peat below is formed by vegetation which at any given time may be growing upon its surface, and is governed by this in its character.

In giving names of this sort to peat deposits, usually some conspicuous species of plant, or sometimes more than one, gives its name to the formation, despite the fact that many others are associated with it, which may be more important as peat formers. Any classification made upon this particular basis would include at least the following types in Michigan:

(1) Elm and Black Ash[1] swamps.
(2) Tamarack swamps, marshes and bogs.
(3) Cedar (Arbor Vitæ) swamps.
(4) Spruce swamps.
(5) Willow and Alder swamps.
(6) Heath (Blue-berry, Cranberry and Cassandra) swamps, marshes or bogs.
(7) Grass and sedge marshes and bogs.
(8) Rush marshes (Cat-tail and Bullrush marshes belong here).
(9) Moss bogs (including Sphagnum bogs).

Elm and Ash swamps are among the most common types of the swamp forest of Southern Michigan and may occur in any locality where the drainage is sufficiently poor, whether peat is present or not. In fact, it is probably true that this type is less frequently found upon pure peat than upon mineral soils, but it may appear as a characteristic forest type upon the poorly drained surface of beds of peat, which have become thoroughly decomposed, and which are rich in mineral matter. Hence in river swamps and delta swamps, on shallow peat approaching muck and humus, they are common. On deeper peat they are found at intervals in the margins of the lake swamps, but there seems to be no way in which these are to be distinguished from those where the substratum of peat is very shallow.

This association of plants occurs upon peat several feet deep at Half

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[1] Throughout this report, at the request of the State Geologist, and as a convenience both to printer and the general reader, English names are used for the different species, but in general in a perfectly definite sense, and a table of the latin equivalents in specific names for the English names used will be found at the end.

Moon Lake, in Seville township, T. 12 N., R. 4 W., sections 5 and 6, and at Mud Lake, in the same township, there was formerly an extensive forest of this type, now cut off, on peat more than four feet deep. Burns[1] reports elm and maple growth (in which the black ash is also an important constituent) at Dead Lake, upon from 5 to 10 feet of solid peat. A very extensive swamp of this general character occurs in sections 7 and 18 in T. 3 S., R. 4 E., in Washtenaw county, where, in places, the peat is more than three feet deep.

(2) Tamarack is a much more commonly recognized indicator of peat deposits than the elm, and is probably a much more certain one as well, especially in the southern part of its range, in Southern Michigan, but it is by no means confined to peat deposits. Throughout the morainal region, wherever there are undrained or poorly drained areas even in the lake plain, there are likely to be found tamarack swamps, and hence a few localities only need be mentioned. Near Ann Arbor the type is poorly illustrated by a small area at the First Sister Lake, three miles west of town. This has been drained and partly cleared, but north of the city a few miles are more extensive tracts about the small lakes, and in the undrained spots in the vicinity of Whitmore Lake, and from thence north on the line of the Ann Arbor R. R. to Durand, they are frequent and typical. Farther north, in Gratiot and Isabella counties, they are again numerous, and still farther north, in the vicinity of Cadillac, extensive areas are occupied by this type. In the borders of lakes the Tamarack frequently is found scattered singly or in groups over the grass and sedge marsh, and such a development is to be seen in the marshes around Lakeland, Livingston county, especially in those which lie north of the station a mile or more. In fact, if is usually true that the species spreads out into an open marshy area near which it may grow, as will be shown later, so that it may be found as a characteristic bog or marsh plant anywhere within its range, in sufficient numbers to become an important element of the vegetation.

The White Cedar, or Arbor Vitæ (*Thuja occidentalis* L.) characterizes a type of swamp which is northern in its distribution, and which has not been observed by the writer south of the central part of the state, but from northern Gratiot county north, the type occurs with great frequency in lake margins, in springy situations, and along the terraces of streams. One of the more southern points at which the type has been observed is at Riverdale, Gratiot county, where such a swamp formerly occupied a sloping terrace at the foot of a gravelly moraine. The accumulation of peat here was small. At Lake Orion, in Oakland county, is another southern locality for this characteristic species, where it occurs in association with the Tamarack and the Black Spruce. This illustrates a fact which should be constantly borne in mind, namely, that while any of these species may occur without admixture of others, in swamps which they characterize, they also frequently are found in mixed associations, so that a tamarack swamp may be a spruce or a cedar swamp as well, or even an ash swamp.

As one proceeds northward, the cedar swamp is more and more of common occurrence, and may indicate extensive peat deposits, or may not. At Hobart, in Wexford county, peat was more than 20 feet deep under a heavy growth of cedar, while at Littlefield Lake, in Isabella county, the peat, under equally good growth, was, in places, less than two feet deep, and nowhere more than four feet in depth.

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[1] Burns, G. P., Formation of Peat in Dead Lake, Mich. Acad. of Science, 6th report, 1905.

Spruce (*Picea Mariana and Picea brevifolia* Peck) swamps, like the cedar swamps, are of more northern distribution in the Lower Peninsula than the Tamarack swamps, but they extend somewhat further south than those characterized by the Cedar, occurring in southern Livingston and northern Washtenaw counties, either as pure spruce swamps or as those in which there is a mixture of Spruce and Tamarack. Such a mixed type occurs at Mud Lake, a mile and a half west of Whitmore Lake, where both Spruce and Tamarack are scattered over a considerable area of deep peat upon the north side of the swamp, while the Spruce is nearly entirely wanting on the south side. In the region farther north, Isabella county and northward, Spruce swamps are of more frequent occurrence and are more dense, while in the Northern Peninsula extensive areas of this type are characteristic features of the greater part of the Peninsula.

In the southern part of the area under consideration, the Willow swamp, or marsh, is a common type. In this the ground is more or less densely covered by shrubby Willows of various species, often accompanied by Poplars, the growth reaching a height of from five to twenty feet, or more. The growth may be very dense upon moderately well-drained peat or may be scattered upon that which is wet. The Willow swamp frequently borders a grass marsh, and the relationship is a genetic one, as will be pointed out below. Small Willow swamps are common over the greater part of the area studied, and are often found occupying the swampy areas along streams where there is little, if any, peat. The Alder swamp is much like the Willow swamp, except that it is usually more densely covered by the bushes, and that these grow to a greater height, and also is more northern in its region of frequent occurrence. Like Willows, the Alder is frequently the dominant growth in the wet valleys of streams, and in the region north of the central part of the Lower Peninsula, Alder swamps are very common, and may develop where there is considerable depth of peat. At Mud Lake, mentioned above, is a considerable area of Willow swamp near the western end of the peat deposit, which has accumulated there.

Alder is the characteristic shrub in a large peat swamp near Half Moon Lake in Gratiot county, and is generally a more or less important constituent of the flora of swamps along streams in the region to the north of the center of the Lower Peninsula, as well as in the other types of swamps. The chief species of Alder found in the Alder swamps of this range is *Alnus incana* (L.) Willd., and while both Willows and Alders may grow in any wet open situation, they frequently grow upon the deepest peat. These plants frequently follow clearing, draining, burning or destruction by floods of other types of vegetation.

Another type of bush cover upon peat deposits, and the one which is more likely to indicate peat of considerable depth in the Southern Peninsula of Michigan than any other kind of woody growth, is that formed by the members of the Heath family, of which the Blueberries, *Vaccinium corymbosum* L., and other species of the same genus are the best known representatives. Heath swamps are rare or absent over very considerable areas in the lake plain district, and in some portions of the morainal areas, but in others, and upon the till plains in the northern and north-central parts of the state, they are of rather frequent occurrence. The various heaths are usually associated with the moss *Sphagnum,* and the locations cited below will usually serve for both types. The association is not invariable, however, and some of the heaths have been found in extensive tracts where little, if any, *Sphagnum* was present, as on sections 25 and 26 in Dexter township, Washtenaw county (T. 1 S., R. 4 E.). Heath swamps are illustrated by a portion of the swamp about Mud Lake, already referred to, by a number of areas between Perry and Lansing, along the line of the Grand Trunk R. R., by several examples near Vestaburg in Montcalm county, in the southwest part of T. 12 N., R. 5 W., and by others in the vicinity of Boyce Lake, Roscommon county, in T. 21 N., R. 3 W. Often with the heaths will be found other shrubs, which, in the southern part of the state, may be quite as conspicuous, or even more so, but for which it does not seem necessary to make a special class here.

The grass and sedge types of marsh or bog are well known and are often called "hay marshes," because they are cut for hay. The prevailing vegetation is grass-like and may be either sedges or grasses or mixtures of the two types, although frequently there are practically no species of one or the other of the two present in quantity. Generally the sedges are found upon rather wetter situations than the grasses, but both grow finely upon peat. The wide "prairies" of Saginaw and Bay counties, extending up into Tuscola and Huron are chiefly sedge marsh, in which various species of *Carex* are the most conspicuous plants, but in the same region there are numerous limited tracts in which the grasses are the chief vegetation. The marshes of the lake borders of the vicinity of Lakeland, Livingston county, and of Four Mile Lake, near Dexter, Washtenaw county, and those along the Detroit and St. Clair rivers are chiefly sedge marshes, although in most cases, all of these pass gradually into rush marshes or bogs as one goes from the shore outward to the lake or river.

As indicated in the preceding statement, the rush swamp or bog is wetter than the sedge type in the majority of cases and may be found associated with it, and, in the localities named above the rush type is found in close proximity, or even intruding upon the other. The plants taken as characterizing this wet type of marsh are the Cat-tail Flag and the Bulrush, and, as is also true of the sedge and grass marshes, both may, and often do, grow in places where there is no peat whatever, but, on the other hand, all may grow upon peat of great depth, though where these plants are present, the peat is frequently very wet and soft.

The moss bogs are those in which some species of true moss is a marked constituent of the surface cover and rarely may be the only type present. The mosses most likely to become dominant in these places are (1) in the wettest places aquatic species of *Hypnum;* (2) in somewhat dryer areas, but still very wet, *Sphagnum;* (3) in the dryest places in bogs, or after they have been drained, *Polytrichum;* or, in shady places, the high ground species of *Hypnum;* with *Polytrichum* not uncommonly occurs the lichen *Cladonia* Sp. The heath bogs mentioned above all have more or less *Sphagnum* present, while the great peat deposit at Capac was densely covered in many places by a species of *Polytrichum,* as was the bog (swamp) at Chelsea, Washtenaw county, now being developed for fuel manufacture.

In discussing these schemes of classification it is evident that if the discussion is to serve any definite purpose, the life relations of the plants concerned in the formation of peat, the principles which govern their distribution, not only areal, but also into associations, and their adaptation to environment, must be carefully considered, since in general peat deposits have been built up by the continued addition of the dead parts of plants which have lived upon the surface of the deposit, while it was being built. It must also be borne in mind that not all such plants are of equal importance as peat formers, since some of them are of less frequent occurrence, are less vigorous in growth, and because of simple structure, furnish less vegetable matter than others.

The subject of the formation of peat has been written upon frequently for more than a century, but the discussion has been carried on mainly by European writers, who have dealt with conditions existing in colder, moister and less variable climates than that of the part of Michigan which is here discussed, and the developments described are evidently quite different from those studied here.

A brief review of the literature makes this apparent, as shown by the following citations:

Geikie[1] states that "these deposits are largely due to the growth of bog mosses and other aquatic plants, which, dying in their lower parts, continue to grow upward on the same spot." "In a thick bed of peat, it is not infrequently possible to detect a succession of plant remains, showing that one kind of vegetation has given place to another during the accumulation of the moss. * * * the lowest part of the peat may contain remains of reeds, sedges, and other aquatic plants which choked the lake. Higher up the peat consists almost entirely of the matted fibers of different mosses, especially of the kind known as Bog-moss or *Sphagnum*. The uppermost layers may be full of roots of different heaths which spread over the surface of the bog."

Jukes-Brown[2] makes the following statements: "In England and Europe generally, some species of moss constitutes the greater part of the mass, but elsewhere other plants contribute largely to the growth of peat. In the English Fen country, peat is chiefly formed by a moss called *Hypnum fluitans,* but in the mountain bogs of Ireland and Scotland the moss is a species of Sphagnum."

According to Sir J. Rennie,[3] many of the peat bogs or "mosses" of Europe occupy the sites of great forests, some of which have been destroyed in historic times. The fallen timber by obstructing the natural drainage, and causing the ground to become wet and marshy has conduced to the growth of mosses which produce peat.

Brown[4] states that "on the continent (of Europe), turf formation is said to be rare on calcareous and frequent on silicious bottoms, though in Ireland the rule does not hold true, probably owing to local circumstances, not permitting of the water draining away as easily as it does in a limestone country generally." Also that 'turf' (peat), has received various names indicative of the plants from which it is derived, such as 'moss-turf,' 'grass turf,' 'heath turf,' 'wood turf,' etc. The Irish often speak of a 'sod' of peat."

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[1] Geikie, A., Class Book of Geology, 1890, pp. 82-88.

[2] Jukes-Brown, A. J., Hand Book of Physical Geography, 1892, p. 211.

[3] Rennie, J., Essays on Peat, p. 65.

[4] Brown, Robert, "Our Earth and Its Story," Vol. 1, 1887, pp. 60-62.

Speaking of the peat of Lincolnshire, Wheeler[1] says: "This peat consists of the remains of mosses, water grasses, reeds, flags, and other fresh-water plants, common to ditches and ponds, the most abundant being the *Hypnum fluitans* and the *Arundo Phragmites.*"

Koller[2] makes the statement that "practically all plants except the fungi may form peat, but the bog mosses are most important, as owing to their spongy nature, they tend to produce a high water level in the pond or swamp."

Of American writers upon the subject, there are two classes, those who have written as geologists and those who have described the vegetation upon the surfaces of various types of peat deposits, from the point of view of the botanist.

Desor,[3] quoting from a letter from Lesquereux, gives as the origin of Cedar swamps along the Manistique river, the following: "When a river overflows its banks, the slimy sediment is deposited, of course, at the edge of the current, and where its force ceases; and thus a ridge is formed along the banks, behind which, on the retreat of the river, there remains stagnant water. This is the origin of peat bogs. The first growth of the still water is Chara, a plant of a peculiar composition, containing a large quantity of silica, and to the decomposition of which I attribute, in a great measure, the formation of the clay found in peat bogs. * * * Next to the Chara comes the Sphagnum. To enable these plants to grow, requires only a hollow in which moisture can lodge and a few fragments of woody fiber." Here follows a discussion of the structure, and properties of Sphagnum, and the writer concludes: "Upon the basis of these facts you may easily follow the operations of nature in the formation of Cedar swamps."

"When a little water remains in a hollow and becomes saturated with humic acid by the decomposition of vegetable substances, Sphagnum immediately establishes itself. * * * As these mosses spread * * * a favorable soil is formed for the Cedars."

Lesquereux[4] later attributed the formation of peat in the Great Dismal Swamp largely to Sphagnum, an observation which later explorers[5] dispute.

The persistence of the idea which Lesquereux advocated, and which is evidently correct for northern Europe and a portion of North America, is shown by its almost universal restatement in geological text-books and by even very recent writers upon peat. This Shaler[6] says: "In the northern section of the United States, speaking of those regions in which the mean annual temperature is below 55° F., the water mosses, especially the species of *Sphagnum*, are by far the most important swamp-breeding plants. * * * Its value as a peat producer is, throughout the section within the glacial belt, probably greater than that of all the other water loving plants."

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[1] Wheeler, W. H., The Fens of S. Lincolnshire, 2nd Ed. 1896.

[2] Koller, T., Die Torf-Industrie, pp. 4-5.

[3] Desor, E., in Foster, J. W. & Whitney, J. D., Report on the Geology of the Lake Superior Land District, Part 2, 1851, pp. 240-242.

[4] Lesquereux, L., "Torfbildung im grossen Dismal Swamp," Zeitschr. der deutschen geolog Gesellsch. IV, 1852, pp. 695-697.

[5] Kearney, H., Report on the Botanical Survey of the Great Dismal Swamp Region. Cont. U. S. Nat. Herb. VI, No. 6. 1901, p. 429.
Also Shaler, N. S., Op. cit. 320-321.

[6] Shaler, Op. cit. pp. 285-286.

This writer, to illustrate the importance of Sphagnum as a peat producing plant, uses the diagram which we reproduce as Fig. 2—one which has been widely reproduced in text-books of geology and elsewhere. It should be noted, in connection with this classic figure, however, that conditions, such as it represents, with Sphagnum as the mat forming, lake covering plant, do not and can not occur in the region here discussed. The real relation of plants in the formation of a cover, such as is here represented, is shown in Fig. 4 of this paper.

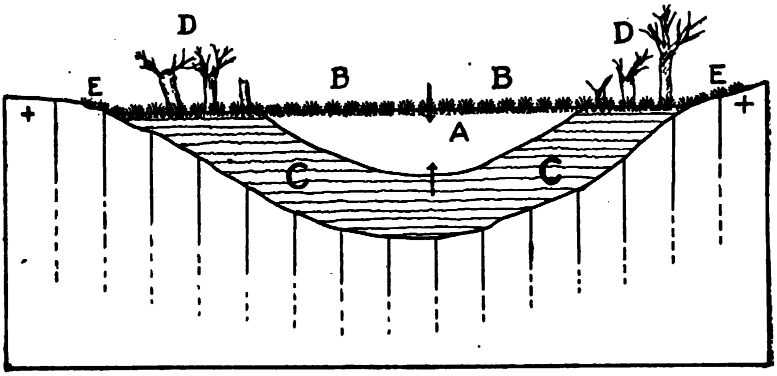

FIG. 2. Reproduced from Shaler, "Fresh-water morasses of the United States, Tenth Annual Report of the U. S. G. S., p. 257. See text and compare Fig. 4.

Dana[1] says: "In temperate climates it is due mainly to the growth of mosses of the genus *Sphagnum*."

Scott[2] has the following: "In northern regions the peat is formed principally by mosses, and especially by the bog moss *Sphagnum*. Elsewhere, as in the Great Dismal Swamp of Virginia, the leaves of trees and various aquatic plants are the sources of supply. * * * "The bogs of northern latitudes are due principally to the bog moss, *Sphagnum*, which forms dense and tangled masses of vegetation, dead and decaying below, green and flourishing above."

Tarr,[3] speaking of the filling of small lakes in the northern states, says: "One form of plant is of particular importance in this respect. A moss, the *Sphagnum*, grows luxuriantly on the shores of these tiny ponds and lakelets and by its life and death, builds a bog which is sometimes several feet in depth."

Ries,[4] in discussing the formation of peat says: "Since most peat is formed from the moss *Sphagnum* peat bogs are formed only in cold, temperate, humid climates, for the reason that *Sphagnum* does not grow in dry air, etc."

Alexander Winchell,[5] on the other hand, as early as 1860, makes the following statement: "Around the shallow margins of these lakes is always a belt, abounding in various forms of aquatic vegetation, which, decaying, form a deposit of vegetable matters, resting upon the marl, from the water's edge to the inner limit of vegetable growth. With the filling of the interior, the shallow belt extends towards the center and the vegetable deposit continually encroaches upon the lacustrine area until the whole lake becomes a peaty marsh."

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[1] Dana, J. D., Text book of Geology, 5th Ed. 1897, p. 107.

[2] Scott. B. W., Introduction to Geology, 1897, p. 133-135.

[3] Tarr, R. S., Elementary Geology, 1897, pp. 190-192.

[4] Ries, H., Op. cit. p.r 58.

[5] Winchell, A., First Biennial Report, Geological Survey of Michigan for 1860-1861, p. 130: Also see Winchell, Geological Studies, pp. 81-82.

From the botanists who have written upon the subject, a somewhat different idea of peat formation is obtained, namely, that many types of plants are concerned, especially water plants.

Cowles[1] makes this apparent in his discussion of the plant societies of the vicinity of Chicago.

Atkinson[2] intimates it in describing the "atoll moors" of the region about Ithaca, N. Y.

Mills,[3] in a recent paper, points out that "Chara, the water lilies, *Castalia* and pond lilies *Nymphaea*, are rapidly reclaiming the bottom of a small lake in Indiana.

Whitford[4] makes an equivalent statement in discussing the swamp societies of Northern Michigan.

Principles Underlying the Relation of Plants to Peat Deposits.

From these citations it would appear that the writers either had different types of formation in mind, had made merely superficial examinations or had studied the tracts which they have described as fixed phenomena. In attempting to reconcile what seem to be conflicting statements the writer began comparative studies of the flora of the peat deposits of Michigan to see if it were possible to discover any law of development by means of which a satisfactory understanding of these formations could be reached. In addition to the studies of the flora, sections of the peat were made wherever practicable, the remains of such plants as could be recognized were studied, and depth of the water level below the surface was noted, and, in many cases, the temperature of the surface and of the subsurface of the soil were taken and compared with that of the air above the surface at the same time.

The following facts were also taken into consideration, which may be stated as follows:

(1.) Relatively very few of the large and more highly organized seed plants can grow entirely submerged in water. Of the (nearly) 2,150 seed plants of Michigan but one Composite, *Bidens Beckii* Torr., a single member of the Campanulaceæ, *Lobelia Dortmanna* L., the majority of the Bladderworts, *Utricularia* species, a few of the Umbelliferæ for a portion of the season, the greater number of the Water-milfoil family, including six species of *Myriophyllum* and two of *Hippurus*, one *Proserpinaca*, and a single *Podostemon*, rarely observed have this ability. The Cruciferæ also have a single representative, *Roripa Americana* (A. Gray) Britt. The Crowfoot family is somewhat more fully represented by two species of *Batrachium*, and two of *Ranunculus*, and the Hornwort family furnishes the well-known *Ceratophyllum*. The Water Lily family sends only its leaves and flowers to the surface or slightly above it, and is an important group, having three genera and six species which may be counted as members of this class.

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[1] Cowles, H. C., Op. cit. pp. 146-147.

[2] Atkinson, G. F., Elementary Botany, New York, 1898, p. 386-7.

[3] Mills, W. M., A Physiographic and ecological study of the Lake Eagle (Winona Lake) Region, Indiana, 28th report. Dept. Geol. and Nat. Res., Ind. Indianapolis, 1904, p. 380.

[4] Whitford, H. N., "The Genetic Development of the Forests of Northern Michigan." Bot. Gaz. Vol. XXXI, No. 5, May 1901, p. 313-4.

Trans. Kansas Acad. of Science, Vol. 15, 1898, p. 23.

The Endogens furnish a much larger proportion of this type of plants, including the important *Heteranthera dubia* (Jacq.) MacM., and the members of the Naidaceæ, the Pondweed family, including *Potamogeton,* but altogether the list is a short one when compared with the total number of plants.

(2.) Of these plants which will grow in water, only a few, mainly *Potamogetons* or pond weeds, can establish themselves at a depth greater than ten feet from the surface, while the majority of submerged plants grow in less than six feet of water, unless it is unusually clear. Reed[1] reports species of *Potamogeton* reaching down into 18 feet of water, and Pieters,[2] in Lake St. Clair, found Potamogetons at about 23 feet, as the maximum depth at which any seed bearing plants occurred.

The writer has frequently tested the depth of the outer limit of the growth of the seed plants and has found it to range from 15 to 25 feet in many ponds and lakes. As this outer or deeper limit is approached the number of species is reduced. The reason for this limitation seems to be that the amount of light and heat which is available at greater depths is not sufficient for the needs of the plants.

To the plants which establish themselves in deep water must be added the Algæ, especially Chara of various species, which grow at considerably greater depths, and which, by their activities, as was pointed out by the writer[3] in previous papers, are instrumental in forming marl deposits, which raise the level of the beds of lakes, and eventually fill them.

On the other hand there are some species of plants which are able to grow luxuriantly in water in which they are unable to reach the bottom, i. e., they grow without root attachment. These are chiefly Utricularias or Bladderworts, and Myriophyllums, and they may be so abundant as to cover the entire surface of a small sheltered lake. *Utricularia vulgaris* L., has thus been noted in a number of bays and small lakes, and more rarely *U. intermedia* Hayne, and on one occasion *U. purpurea* Walt. was the species. In exposed lakes these floating plants are blown about, and are often thrown up on the shore in considerable quantities, hence in such lakes they are not usually important factors in the flora.

(3.) There are very few plants that grow partly submerged, which will grow at a depth greater than six feet, while many of this type, and among these, the most important of the peat forming species, do not grow where the water is over two feet in depth.

Among the plants which have this habitat are the cat-tail flags, *Typha,* the Bur reeds, *Sparganium,* especially *S. eurycarpum* Engelm., the Water-plantain, *Alisma plantago-aquatic* L., several Arrow-heads, *Sagittaria* species, some grasses, especially *Zizania aquatica* L., the Wild or Indian Rice, *Phragmites phragmites* (L.) Karst, Reed-grass, and *Panicularia fluitans* (L.) Kuntze, Floating Manna-grass. Among the members of the sedge family are many forms which grow in shallow water, the one which reaches the greatest depth being *Scirpus lacustris* L., the Lake Bulrush, which, in Saginaw bay, grows in water more than six feet deep. Other important plants of shallow water are species of the genera *Carex* and *Eleocharis,* also sedges. The Pickerel-Weed Family furnishes *Pontederia cordata* L., the common Pickerel weed. One other important species should be mentioned, although already listed among the wholly submerged plants, namely, the Yellow Pond Lily, *Nymphæa advena* Soland, which grows sometimes in water more than six feet deep and frequently forms very dense masses of plants of large extent, as do also the White Pond Lilies, *Castalia* sp.

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[1] Reed, H. S., The Ecology of a Glacial Lake. Bot. Gaz. Vol. XXXIV, Chicago, 1902, p. 129.
[2] Pieters, A. J., "Plants of Lake St. Clair." Bull. Mich. Fish Commission, No. 2, 1894.
[3] Davis, C. A., Jour. Geol. 8 : 485 and 498. Also Report Mich. Geol. Survey, 8 : 66-96.

(4.) Plants which grow on the dry land, or in moist soil, will rarely endure conditions where the soil is constantly saturated with water, hence they are unable to grow in such places. This seems to be due, in part at least, to the lack of available oxygen supply for the roots. A few plants growing habitually in wet places, have special adaptations to enable them to get air for their roots, and for other parts where it is needed. The best illustration of this adaptation among our native plants is found in *Decodon verticillatus* (L.) Ell. the Swamp Loosestrife in which large masses of thin walled tissue, called aerenchyma[1] develop on the stem and the pendulous branches where they come in contact with the water and apparently serve as aerating organs. The thickness diminishes above the water, the tissue changing into ordinary cortical tissue. This plant is more fully described in another section of this report. In the Tamarack a possible aerating system was observed by the writer in 1902 in the swamps where the water level was abnormally high. This consisted of very long (some a yard or more) root-like organs sent off from the older roots above the water level. Structurally these organs were composed chiefly of parenchyma and were very delicate, reddish in color and of varying thickness. Other forms of adaptation for this purpose are the large air passages which are found in the petioles of the leaves, and in the stems of the pond lilies and of many of the rushes and sedges growing in the water or in marshy soils.

(5.) In addition to the sensitiveness to lack of air in the soil, many plants are very sensitive to shading, to the presence of injurious dissolved substances, such as the ulmic, humic acids, etc., developed by the partial decomposition of vegetable matter, and to the constant low temperature about their roots, while their leaves are exposed to very varying and often high temperatures from the sun's rays.

(6.) Nearly all species of plants are affected by a change of climatic conditions, growing more vigorously in warm than in cold climates, and seem to be less sensitive to shading, as the average temperature of the growing season and also the light intensity increases.

The Formation of Peat in Depressions.

In considering these few elementary facts of plant growth in their relation to the schemes of classification given above, it is evident that depressions filled with water to a depth greater than 25 feet, would seldom or never be filled by plants of a type above the algae, growing from the bottom and gradually filling the basins by their growth and decay. Such basins must be filled either by the algae, by floating species of seed plants with no attachment to the bottom, by sedimentation from streams, by accumulation of débris from the shores, or from plant growth extending out from the shores, or by combinations of two or more of these methods. That is, in general, they are filled from the sides and top, if peat is the filling material, and the deep basin, if it were originally filled with water, must be filled in such a fashion whatever its origin, under such conditions as prevail in Michigan.

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[1] Schenck, H., Ueber das Aerenchym, ein dem Kork homologes Gewebe bei Sumpf-pflanzen, Pringsheim's Jahrbucher Bd. XX, 1889.

Formation of Peat in Shallow Depressions.

(a) Making application of the principles to shallow depressions, it is apparent that if these are less than 25 feet in depth, such plants as will grow in water of that depth will establish themselves in the deepest parts, and will eventually form a slowly rising deposit upon the bottom, assisted by other sediments, which may be derived from the tributary streams or from vegetation in shallower parts of the depression. As soon as this has been raised near enough to the surface of the water to enable the shallow-water plants to grow these establish themselves, and because of their greater luxuriance of growth, and firmer tissues they build up the deposit faster, until the water surface is reached, when a still greater number of plants are able to grow. When the surface of the deposit has been raised above the water level, the conditions are again improved, and again the plants are increased in number of individuals and of species, but here a new factor in the progress of the up-building comes in, for the dead material is now brought into contact with the air, and the heat of the sun, which dry out the excess of water, permit the growth of organisms producing decay, and, when a certain amount of elevation above the water level is attained, there can be no further building up, because of the drying and the thorough decay of all the dead parts of plants which fall to the surface.

No case is ever so simple, probably, as the imaginary one just cited, because of the complications which would arise in the course of the filling from fluctuations of water level, interference with established drainage, and the slow settling of the mass of sediment as it was built up, the failure of certain species of plants to become established, and the excessive development of others, the unfavorable occurrence of certain kinds of soil at the bottom of the depression, aiding in this. Thus, in many cases, for some cause not known, Chara seems able to hold the entire bottom of the deeper types of lakes and by its growth fills them with marl, upon which the seed plants establish themselves very slowly. Such deposits are illustrated by Cedar and Marl Lakes in Montcalm county, by Mattison Lake in Gratiot county, Nich-e-waugh Lake, Sec. 25, Green Oak township, Livingston county, and Four Mile Lake in Dexter township, Washtenaw county, and many others. In these there are usually large areas of shallows upon which no vegetation appears except Chara, *Scirpus lacustris* L., the bulrush and scattering plants of some species of *Potamogeton,* frequently very much dwarfed, together with the floating *Utricularia vulgaris L.* But eventually from these plants, and by the addition of organic matter from other sources, the soil becomes less calcareous and later peaty, and then other plants appear, and filling follows the usual course. At Nich-e-waugh Lake this process is now going on around the shores and upon an island of marl upon which the water was about a foot deep in June, 1904, and which was nearly covered by a growth of *Nymphaea advena* Soland, the Nuphar or Yellow Pond Lily, with which were growing species of *Potamogeton, Utricularia* and *Myriophyllum* in an impure marl in which the organic matter was plainly visible. In other portions of the shallows along the margin *Typha latifolia L., Scripus lacustris L.,* and *Decodon verticillatus* (L.) Ell. had established themselves forming a zone shoreward from the Nuphar.

The water level of this lake was formerly higher than at present and upon the gently sloping terrace was a shallow layer of peat, upon which, and extending out into the shallow water on to the marl, were *Typha latifolia* L., forming a broad zone and in places mixed with *Phragmites Phragmites* (L.) Karst., inshore from which was an open marsh, with a shallow substratum of peat, which merged into a Tamarack swamp, where the peat was still deeper.

At Cedar Lake this process of peat formation had been developed until at the time when the land was cleared, the filled portion of the lake was occupied by a cedar swamp extending over the entire peaty area, upon which the peat was in no place more than three feet deep and usually less, while at Marl Lake, less than a mile away, there was an entire absence of peat over a great part of the marly shallows, and only very sparse vegetation, consisting chiefly of bulrushes, in a few spots upon them.

In other places, parts of the lake where the water is shallow, where there is no apparent reason for their absence, plants will not occur. The western shore of Bass Lake in Montcalm county and the northeastern shore of Whitmore Lake, in southern Livingston county as well as other parts of this lake have very few plants upon them. At Bass Lake the soil is very hard and stony which may prevent the establishment of such plants as may get a foothold, while at Whitmore Lake, the fact that the plantless area is exposed to strong winds and is sandy in consequence, may be an explanation of the lack of vegetation, since the waves created by strong winds may prevent some species from getting a start, while ice blown by the winds during the spring may tear out others which have started. A soft oozy mud bottom seems much more favorable for the growth of many types of water plants than either hard clay or shifting sands. This may be due to its more easy permeability, or to the fact that such soils are richer, which, according to Pond[1] would increase the growth of water plants.

From the foregoing it may safely be inferred that as the deposit was built up, there would be a change in the character of the vegetation as the water decreased in depth and that the plants concerned in the formation of the deposit would occupy such places as were suited to their requirements in a definite order. The same conclusion would be arrived at by studying the plant growth from the margin to the center of any shallow lake which is in the process of filling, for it would be found that the plants definitely arrange themselves according to the depth of the water, and if the slope of the bottom is uniform and the character of the bottom practically the same throughout, the plants of given types usually grow in well marked bands or zones, entirely around the shores. The descriptions of such lakes are numerous in botanical literature both European and American and the zonal arrangement of the plants in these locations a well recognized ecological phenomenon.

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[1] Pond, R. H., Report U. S. Fish Commission, 1903.

In studying a series of such lakes the conclusion must be reached that as fast as conditions are favorable, the vegetation of the shoreward zones, i. e. that growing in shallower water, moves toward the center, and is replaced by that from nearer the shore. This is due not only to the shoaling of the water and the increased light which reaches the plants growing upon the bottom, but also to increased heat, since the shallower water is more quickly warmed than the deeper, to improved aeration due to more frequent stirrings by wave and surface current-action, and to the improved physical and chemical condition of the substratum. In the majority of more than fifty small lakes and ponds studied in various parts of Michigan during the present investigation, the order of succession of seed plants was as follows: First, in the deeper water appeared the Potamogetons, often spreading over the whole central part of the lake, as in Rock Lake in Montcalm county, at a low water stage a few years ago, and several small lakes seen in Oakland county. Shoreward of this was frequently a partial or complete zone of the White or Yellow Water Lilies or both. In some small shallow ponds the Yellow Pond Lily was found covering the entire surface of the depression with no other plants visible, and at Mud Lake, Washtenaw county, both the White and Yellow Water Lilies, *Castalia tuberosa* (Paine) Greene, and *Nymphaea advena* Soland, nearly covered the surface of the remaining parts of the lake but associated with various species of Potamogeton and Utricularia. In many cases this group or zone was bordered by a wide one of the Lake Bulrush *Scirpus lacustris* L., in which were to be found on the outer margins, the plants of the outer zones, and shoreward were the sedges, or frequently, a well marked zone of *Scirpus Americanus* Pers., the "Three Square," with some other rush-like semiaquatics. At Whitmore Lake the common plant of this zone is *Eleocharis palustris,* R. & S., the Creeping Spikerush. With this, some of the sedges, various species of Carex, occur, establishing themselves above the water line, the species apparently depending upon the kind of soil and the amount of drainage, as well perhaps, as upon the accident of becoming established first.

These characteristic plants were sometimes arranged in limited areas rather than zones, or were wanting, or were replaced by other types, but they were present so often that they should be mentioned as those usually found.

The movement forward in any zone is in most cases a relatively slow one, possibly dependent upon recurring cycles of dry seasons, as is the change of condition which makes the movement possible, and on the border between two zones occurs a mixture of the characteristic plants of the two, to which the term "tension line" has been applied by various writers, in which the shoreward plants are at first in the minority, then in about equal numbers and then in the majority, as the shallow water type is generally more aggressive. Thus in those lakes where the Yellow Pond Lily is abundant, its large, thick and numerous leaves resting upon the surface or rising above it, so shut off the light, while its large rhizones and spreading roots occupy the soil below, that the submerged Potamogetons do not thrive where it is well developed and disappear when forced to compete with it, while in those lakes where the Yellow Pond Lily is absent, as at Silver Lake, Green Oak Tp., (Sec. 22, T. 1 N., R. 6 E.) the Potamogeton may occupy a much wider zone.

When the surface of the water is nearly reached by the slowly rising bottom, and the semi-aquatic types of plants give place, through the same sort of competition, to those which can live in moist soils on land, for from this time on, during some portions of some seasons, the surface of the soil is above water, and plants growing upon it must be able to accommodate themselves to this condition of variation of the water level.

Peat Formation upon Flat Areas: In applying the principles stated above to the flat, undrained areas, and to wet slopes, a slightly different set of conditions prevail, for here during a part of the year the water before peat deposition begins, may be merely sufficient to keep the soil moist or wet, while during the remainder of the time, in rainy seasons, it is possible that it may cover the surface in a thin sheet. In such cases, the conditions are much like those which exist upon the surface of a filled depression, and usually the plants which grow upon the two types of surface are identical in character and often in species. If it is assumed that the original surface was bare at the outset, such plants as will grow upon wet soils will establish themselves, and, in a relatively short time the cover of vegetation causes the drainage to become poorer, by retarding the run off. The first plants in such cases may be some species of Liverwort, like Marchantia, or of moss, like some of the Hypnums, and in cool and damp climates, of Sphagnum, while in dryer ones it may be rushes, sedges, or grasses at once. This, in turn, makes the soil still wetter, and favors the accumulation of vegetable matter in a partly decayed state upon the surface of the ground and this still more retards the flow of water, until the surface may be covered with standing or slowly moving water for a considerable portion of the year. These conditions eliminate many species of plants which may have established themselves for a time, because they are not able to live where the water level is so high, and the suppression of these sensitive forms, gives the more hardy species full opportunity, and soon the ground is all occupied by species which are adapted to the conditions. If the water level is continuously raised as the surface is elevated by vegetable accumulations, these plants will usually continue to form the dominant growth and the peat which is deposited will be made up of the remains of relatively few species and will be homogenous. The shallow beds of peat which are formed in the marshes about Saginaw Bay seem to belong to this type, the dominant plant forms being principally sedges of the genus Carex, with a few species of grasses associated with them. Certain types of terrace and valley peat deposits also belong in this group, especially those where the terrace or slope is watered by the water from seepage springs, which are constant sources of supply. These sedges, frequently *Carex stricta* Lam. are the chief surface plants of these types, and from the hygrophilous (water-loving) character of these, have probably been so from the beginning of the formation. In the northern and north central part of the Southern Peninsula, some of the mosses, not infrequently Sphagnum, may occur as a member of the surface association of plants, along with certain tree species, especially the Arbor Vitae. Such an association suggests the probability that it represents a mature condition of the deposit, in which the water level is not as high as it was in earlier states, but the type of deposit has not been carefully studied, and the series traced through.

If, however, there are periods in the growth of the deposit when the water level is rapidly raised, and remains high for a time, or is lowered and is low for a considerable period, then other types of plants establish themselves, the original flora is displaced and the deposit will take on a heterogeneous character, varying with the type of plant growth, and exhibiting well marked stratification, which makes the changes.

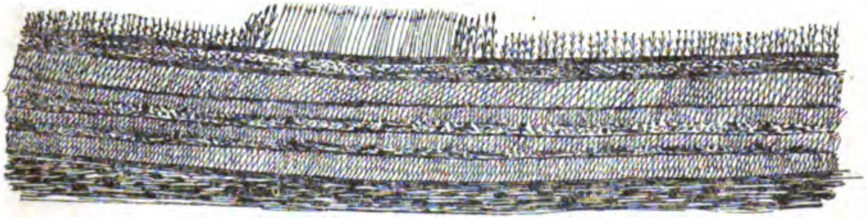

FIG. 3. Diagram showing structure of a peat bed built up from the bottom by successive elevations of water level.

Such changes may be due to the establishment of better drainage or to clogging of the drainage outlets, or to the irregular but no less potent, periodicity of rainfall and drought periods, which has been pointed out by Harrington,[1] Horton,[2] Rafter,[3] Lane[4] and others.

The accumulation of peat is a slow process, under any conditions, and during the building up of any thickness of it, there will be many periods of excessive dryness, or of great rainfall and these would inevitably cause changes in the soil, and the soil water and drainage conditions, sufficient to make radical changes in the flora, provided that they were of sufficient duration, periods of at least more than two successive years being necessary in most cases to affect a marked change.

How Depressions are Filled from the Sides and Top: The opposite extreme in the system of classification proposed above, the type of peat deposit formed by filling deep basins from the sides and top, furnishes a rather more complicated case than any of the others discussed, because here the material is accumulated in deep water, and to a considerable extent the action of the waves and currents must be taken into account.

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[1] Harrington, M. W., Bulletin C, Weather Bureau, U. S. Dept. Agric. Washington, D. C.

[2] Horton, R. E., Water Supply and Irrigation Paper No. 30, U. S. G. S.

[3] Rafter, Geo. W., Water Supply and Irrigation papers, No. 80, U. S. G. S. Washington, 1903, pp. 13-15.

Lane, A. C., Michigan Geological Survey Report, Volume VII, Part 2, pp. 38-39.

The early stages of the formation of such deposits are probably to be found in the deeper lake basins which have more or less complete zones of aquatic plants, such as those described above, and which may cover the shallower parts of the basin, as at Whitmore Lake, Half Moon Lake, and others in various parts of the state. These rings of vegetation may be broad or narrow according as the slope of the bottom is gradual or steep, and the debris from the decay of this, and such fine mineral matter as is stirred up by the waves, or is brought in by the inflowing streams, is spread over the bottom, along the surface of the vegetation zones, where it is held by the leaves, stems and roots of the plants, and in coves or indentations in the shore line, to which it is borne by the more or less constant shore currents, caused by the winds.

Such deposition as this, however, must be exceedingly slow and basins in which it is the only method show little filling, even where relatively small and shallow, as in the case of Independence Lake in Webster township, Washtenaw county, Park Lake in the same township, and Rock Lake in Montcalm county, which though in the neighborhood of filled basins have no considerable deposits of peat.

In this type of basin where filling has progressed so far that it is evident that it will soon be completed, but is still going on, the process of filling may be studied. The first marked difference between this and the type where no filling has been done, which the basin presents, is a marsh of greater or less width, the lakeward extension of which is afloat, and which is of the nature of a mat or raft, built up by the interwoven rhizomes or horizontal stems of sedges or rushes. These apparently are able to build the mat out from the shore and the filling of the water is accomplished under the margin of the mat.

Superficially the sedges resemble grasses, and in the ordinary or vegetative condition are distinguished from them mainly by having, in the kinds more important in this discussion, triangular stems, not prominently jointed nor hollow, while the grasses have hollow, jointed and round stems. In addition to these vegetative characters, the fruiting parts of the two types are very different. *Carex* is the most important genus of the sedge family, in number of species and is the one furnishing the species most efficient in the construction of mats out over the surface of the water, and of the genus, the species which in the region studied by the writer is by far the most important in this work, is *Carex filiformis* L.

This plant is not easily distinguished in the vegetative form, from other species of the same genus which grow in similar situtions, but it has very long, tough, narrow leaves, tapering to a fine thread-like point, which grow from a horizontal, subterranean or subaquatic stem, or rhizoma, from the nodes of which also grow the long slender roots. These underground stems will often grow horizontally more than a foot in length in a season, bearing at the end a terminal bud, from which new plants rise to send out in turn a new series of horizontal stems. When conditions are unfavorable for the rhizomes to grow outward into open water, they sometimes grow diagonally downward over the edge of the mat, the terminal bud developing just beyond the margin, and thus, the mat is strengthened as well as extended by the growth of the plant. These stems are tough, buoyant, and very durable, and it is by the interlacing and development of these and their roots that the mat mentioned above is built up and out over the water. Other plants of the same family, and others not related, are occasionally important in building similar structures, but the mats formed by these are not so extensive nor as firm as those built by the *Carex filiformis*.

Extensive bogs and marshes are formed by these plants by building out from the shores of lakes, the felted and interwoven mass of their submerged stems and roots making a buoyant structure capable of supporting considerable weight. It is important to note here that the sedge can, and does, grow with its rhizomes submerged a foot or more below the surface of the water, and with roots extending much farther downward.

The filling of lakes by similar developments has been described by Shaler,[1] Ries,[2] and others, but as the process as noted in Michigan, is essentially different from that described by these authors, and is of much interest and importance in the region under discussion, the following account and illustrations are given:

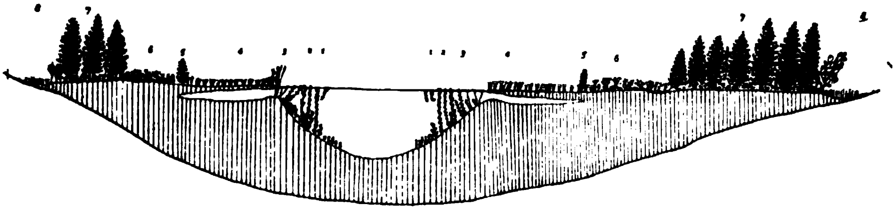

FIG. 4. Diagram showing how plants fill depressions from the sides and top.

Legend to Fig. 4.
1. Zone of Chara and floating aquatics.
2. Zone of Potamogetons.
3. Zone of Water Lilies.
4. Floating Sedge mat.
5. Advance plants of conifers and shrubs.
6. Shrub and Sphagnum zone.
7. Zone of Tamarack and Spruce.
8. Marginal Fosse.

The sedge mat being the most important and the most frequent in the region under discussion will be the one chiefly considered, and the account below will refer principally to this type.

It seems probable that the sedges are somwhat dependent upon a certain amount of preparation of the parts of the lake over which they advance, before they can proceed with their constructive work, because the margin of the mat and the water beyond it, are usually occupied by a considerable number of species of floating and submerged water plants, some of which, like the Nuphar and Potamogetons, have extensive roots and rhizomes, and require some sort of soil in which to grow. In other instances the plants along the margin of the mat are wholly unattached, such as the Bladderworts, Utricularia species.

It is possible that these plants are the pioneer forms which start the building and aid in extending the growth lakeward by furnishing a sort of substratum for the roots and rhizomes of the sedges, although in one case at least, that of Long Lake, in Fenton township, Genesee county, the rhizomes of the Carex were found extending into open water, and it seems certain from numerous examinations in various places that the mat gets no support from this substratum. The mat is actually floating for some distance from its outer margin, because any added weight causes it to sink rapidly, while holes through it not only end abruptly in water, but the water which pours up through these, wherever the surface is weighted down, is clear, and quite free from suspended matter. Near the lakeward edge, the mats are from a few inches at the margin, to about 18 inches or two feet in thickness back where the weight of a man may be safely borne. In a series of sections through the mat, from the water margin shoreward, the water will be found to become more and more full of finely divided matter as one proceeds toward the shore, until, at a variable distance from the water's edge the deposit is nearly solid and the mat no longer floats.

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[1] Shaler. Op. cit. p.
[2] Ries. Op. cit. pp. r. 56-57.

A study of the mat itself in the same sections, will show it to be of no great toughness, for holes are easily dug with the hands, but the material of which it is made is readily seen to be, in all its parts, the rhizomes and leaves of the sedges, which retain their structure and characteristics throughout the entire thickness of the mat, below which, all structure abruptly ceases, even where the mat is grounded.

This structure makes it evident that the peat deposit is not built up by the sinking of the mat under the added weight of the growth of vegetation of successive seasons, for in that case there would be a transition structure from the definitely fibrous and coherent mat, to the structureless mass below, and there would be not a space of open water between the mat and the rest of the deposit. Therefore the material which accumulates under the mat must come from the dropping down of débris from above, from the under side, and from the margins, in which case it may possibly be carried under it by some system of circulation, the causes of which need not be discussed here.

Whatever the causes of this accumulation, as the mat spreads out from the shore, at a fairly constant distance from the margin, the peat becomes rather dense and solid, so that the bog no longer floats, loses much of its quaking character and becomes firm. When this stage is reached, other plants than the sedge and the rushes begin to establish themselves upon the mat, and these eventually build up the surface, and by shading and overgrowing it destroy the sedge, which is sensitive to shading. It is possible, however, even after this has happened to show that the sedge has done its work by making a section through the superficial layers of the deposit to the level where the mat was formerly, for the remains of the rhizomes of the sedge may be found at that level in greatest abundance, as will be shown later. The peat below such a mat is usually fine grained, structureless and well decomposed, and nearly black in color.

Effects of Consolidation and Raising the Surface of the Deposit.

In no other type of peat deposit is it possible to see so clearly the marked effects which are caused by a slight change in the level of the surface, upon the flora growing above the deposit. As long as the mat is afloat the sedge is able to grow freely and keep out all competitors except such as grow in the water associated with it. Rarely the mat itself is pushed above the water level by being compacted and compressed laterally by ice thrust in the winter.

When the mat has become grounded, however, the surface is gradually built up until it is above water, at least a part of the year, and other plants appear in large numbers and in considerable variety, but always in a definite order. The number of species is not large for each level built up, but when that level has been reached, some or all of the species which should be present appear, and these, because of greater vigor in growth, in a variety of ways such as height, greater amount of foliage, and of roots, etc., usually cause the disappearance of the sedge. While the species of Carex mentioned is the most efficient and the most abundant and frequent of the genus in the sedge mats it is not the only one which is able to make extensive growths of the sort, *Carex aquatilis* Wahl., *C. Sartwellii* Dewey, and *C. utriculata* Boott, all having been noted in such mats, either alone or associated with *C. filiformis* L.

It is apparent that if the sedge mat, as long as it is afloat does not support any considerable number of other types of plants, and if the peat is gradually built up under the mat until that no longer floats, the sedge is the chief agent in forming the deposit, not even second to the water plants which grow in most cases at its outer margin. While it is not clear how the consolidation comes about, the present investigation has led to the conclusion that in no other way than that stated can the existing observed facts be accounted for, unless, as suggested above, a remarkable and not easily explained circulation exists in the water below the mat, by means of which the débris which is formed outside its edge is carried under it for considerable distances. This does not seem probable, but no final statement can be made at this time.

Among the lakes visited in which the sedge mat and attendant phenomena are well illustrated in Mud Lake[1] on the line between sections 1 and 12, Webster township, Washtenaw county, (T. 1 S., R. 5 E.). This is one of a series of depressions in a till and gravel plain lying north of Ann Arbor and bordered at the northwest by a strong moraine. These depressions are, or have been, occupied by lakes in various stages of the process of filling with peat. Of these Mud Lake is probably in the most advanced stage before the actual closing and complete covering of the waters occurs. The remaining open water is now divided by narrow strips of sedge and broken by islands of other plants, and that which would be open is well nigh covered with leaves of the pond lilies, *Castalia reniformis* (Paine) Greene and *Nymphaea advena* Soland, with *Potamogeton* of various species and other aquatics intermixed.

In the smaller holes in the sedge mat near the larger spaces of open water the *Nymphaea* is the usual lily, and associated with it are *Typha latifolia* L., the Cat-tail, growing on the shoaler places, *Pontederia cordata* L. the Pickerel-weed, and *Peltandra Virginica* (L.) Kunth., the Arrow-arum, which are able to establish themselves in water a foot or more in depth upon a very poorly compacted substratum. In places along the margins of the open pools the Lake Bulrush was present either reaching out over the lily plants or forming clumps which were minature islands and occasionally small groups of *Decodon verticillatus* (L.) Ell., the Swamp Loosestrife, grow in the margin of the sedge mat, or forming small clumps in the shallow water. These islands are evidence that the bottom of the pools is not very far from the surface in the places in which they occur, although it may be much deeper in areas where other plants occur.

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[1] Since the following account was written, a description of this locality has been printed. See Pennington, L. H., "Plant Distribution at Mud Lake." Report Mich. Acad. of Sci., Vol. VIII, 1906.

The sedge mat upon the south and east sides has a very different character upon the shoreward margin from that of the north, but upon the lakeward areas it is very similar all around to the open water except as noted below. It is wide, very wet, the sedge plants growing in from 8 to 12 inches of water, floating, so that it is strongly shaken when walked upon, and for several hundred feet back from the open water the principal plant species present is *Carex filiformis* L. with which is associated in the wettest places—often small depressions among the sedge plants—a few surviving and stunted plants of the Yellow Pond Lily, and in the water, overshaded by the sedge culms and leaves, is abundant *Utricularia intermedia* Hayne, which is a common plant also in open water as well. With this are algae, and the minute seed plants *Lemna,* frequently *L. trisulca L.*

In addition to these a more conspicuous plant was *Typha latifolia L.* which was scattered all over the marsh and entirely replaced the sedge at the east end and upon the west and northwest sides of the lake. In some places back from the edge of the mat, where the *Typha* is found in the marsh, the turf seems firmer than in others, but in general the conditions where this plant is found are quite as wet or wetter than in the pure sedge mat.

A conspicuous plant upon the sedge marsh and somewhat common with the *Typha* and one of some significance with regard to the dryness of the substratum, i. e. the height of the water level, is the Marsh Shield-fern, *Dryopteris Thelypteris* (L.) A. Gray, which, although it is found in the young stage in the western part of the sedge mat, where the sedge plants are somewhat scattered, is the dominant plant upon the areas of the mat where for some cause the surface level is very slightly higher and the turf firmer and more compact, possibly from ice thrust in the winter or the accumulation of drift material on which the sedge plants do not thrive, or are absent altogether.

This fern is very light green in color, in this kind of situation, so its position is easily seen, and it is usually accompanied by quite an extensive flora which has reached out from the more stable, open and better drained marshes near the shore, and with these, in low spots, usually are remnants of the aquatic and semi-aquatic vegetation which the sedge has not crowded out completely. The plants of this association which are from the shoreward regions, are:

Bochmeria cylindrica (L.) Willd., False Nettle. Very common.
Eupatorium purpureum L. Joe-Pye Weed.
Eupatorium perfoliatum L. Thoroughwort.
Aster junceus Ait. Rush Aster.
Lycopus communis Bicknell. Bugle-weed.
Larix Laricina (Du Roi) Koch. Tamarack.
Osmunda regalis L. Flowering Fern.
Galium spp. Bedstraw.
Triadenum Virginicum (L.) Raf. (*Elodes companulata* Pursh) Marsh St. John's wort.
Impatiens biflora Walt. Spotted Touch-me-not.
Viola alsophila Greene (*Viola blanda palustriformis,* A. Gray.) Marsh White Violet.

Carex limosa L. Mud Sedge.
Ophioglossum vulgatum L. Adder's Tongue Fern.
Limnorchis hyperborea (L.) Rydb. (*Habenaria hyperborea* R. Br.) Tall Leafy Green Orchis.

The list of those from shallow water is smaller and includes the following:

Sagittaria latifolia Willd. (*S. variabilis Engelm.*) Broad-Leaved Arrow-Head.
Peltandra Virginica (L.) Kunth. (*P. undulatà* Raf.) Arrow-arum.
Typha latifolia L. (not common here.) Cat-tail.
Carex filiformis L. Slender Sedge.

This list is given because of the fact that most of the species from the shoreward group are quite constant in their association with the marsh shield fern, and, while all of them are not invariably found with it, in such places, some of them are, and they undoubtedly help prepare the surface of the sedge mat for succeeding plant associations. The Tamaracks which are found with the ferns thus far out upon the bog are usually of small size and quite young, but as soon as they get tall enough to produce shade they are accompanied by a less number of species, some of them evidently persisting from the open fern association.

Under a group of young Tamaracks, which were 8 to 10 feet in height, and formed a rather dense thicket 10 to 15 feet in diameter, somewhat farther shoreward than the most advanced stations of the ferns, the following species were found and the association is typical on this sort of growth:

Dryopteris Thelypteris (L.) A. Gray. Marsh Shield-fern.
Viola alsophila Greene. Marsh White Violet.
Onoclea sensibilis L. Sensitive Fern.
Menyanthes trifoliata L. Buck-bean.

And little else, the shade being quite dense. The *Dryopteris* in these thickets was much taller and larger and of darker green than that in the open bog.

In some of the areas of fern it was evident that another change had begun, for upon these were small and apparently recently established colonies of Sphagnum, practically the only growth of the moss upon the south and east sides of the entire marsh area. Still farther towards the shore the areas of fern were somewhat less numerous and the sedge became more dense and taller, and the surface of the marsh seemed a little lower, with more water upon it. Here the *Carex filiformis* was mixed with two other species, possibly more, but certainly with *Carex Sartwellii* Dewey, Sartwell's Sedge and some *Carex teretiuscula* Good, the Lesser-Panicled Sedge.

Here also were found associated with the sedges, more or less frequently, *Menyanthes trifoliata* L. and *Comarum* (*Potentilla*) *palustre* (L.) Marsh, the Marsh Cinquefoil.

Bordering this area and extending along the whole length of the south and east sides of the marsh was a narrow zone of shrubby willows of several species, and immediately back of this, away from the marsh, was a belt of tamaracks, several rods, or even more, in width. The plants found beneath the tamaracks which were from 20 to 40 feet in height, were as follows. In considering this list it must be remembered that the water level is below the surface of the roots of the trees, and some of the shrubs, so that these form elevated stools, covered with sufficient soil to give root-hold to various plants, hence so far as water level and drainage is concerned the species may have a considerable variety of habitat in what is often treated as a single type. No attempt is here made to indicate the water relation of the different species, although some species seemed practically confined to the low hummocks formed by roots and stumps, and others to the depressions between these; all were well within the shade of the tamaracks and were thrifty in this situation.

Woody Plants of the Tamarack Zone.

Acer rubrum, L. Red Maple.
Betula pumila L. Dwarf Birch.
Cornus stolonifera Mx. Red Osier.
Cornus candidissima Mill. Panicled Cornel, or Dogwood.
Gaylussacia resinosa (Ait.) T. & G. Huckleberry.
Ilex verticillata (L.) A. Gray. Black Alder.
Juniperus communis L. Ground Juniper.
Picea brevifolia Peck. Black Spruce.
Rhus Vernix L. (*Rhus venenata* D. C.) Poison Sumach.
Rosa Carolina L. Swamp Rose.
Rubus Americanus (Pers.) O. A. F. Dwarf Raspberry.
Solanum Dulcamara L. Wild Potato. Nightshade.
Ulmus Americana L. White Elm.
Oxycoccus Macrocarpus (Ait.) Pers. (*Vaccinium Macrocarpon* Ait.) Large Cranberry.

The Maples, Elms and Spruces were all small, the shrubs mostly well developed plants, but not old or large. Of herbs, the following list contains the most prominent species, and those which are probably most significant in the history of the development of peat.

Dryopteris Thelypteris (L.) A. Gray. Marsh Shield-fern. Here very abundant and thrifty.
Boehmeria cylindrica (L.) Willd.
Carex sterilis cephalantha Bailey. (*C. echinata cephalantha* Bailey.) Prickly Sedge.
Carex leptalea Wahl. (*C. polytrichoides* Willd.) Bristle-stalked Sedge.
Carex tenella Schk. Soft-leaved Sedge.
Carex trisperma Dewey. Three-seeded Sedge.
Coptis trifolia (L.) Salisb. Goldthread.
Equisetum fluviatile L. (*E. limosum* L.) Swamp Horsetail.
Eriophorum polystachyon L. Tall Cotton-grass.
Galium trifidum L. Small Bedstraw.

Glyceria nervata (Trin.) Nerved Manna-grass.
Panicularia nervata (Willd.) Ktze.
Impatiens biflora Walt. (*I. fulva* Nutt.) Spotted Touch-me-not.
Leptorchis Loesellii (L.) Mac M. (*Liparis Loesellii* Rich.) Fen Orchis.
Unifolium Canadense (Desf.) Greene. (*Maianthemum Canadense* Desf. False Lily-of-the-Valley.
Menyanthes trifoliata L. Buck-bean.
Osmunda cinnamomea L. Cinnamon Fern.
Osmunda regalis L. Flowering Fern.
Comarum palustre (L.) Marsh. (*Potentilla palustris* Scop.) Marsh Cinquefoil.
Rumex Brittanica L. Great Water-dock.
Sarracenia purpurea L. Pitcher-plant.
Sphagnum. This occurred sparingly in depressions below the water level.
Spathyema foetida (L.) Raf. (*Symplocarpus foetidus* Nutt.) Skunk Cabbage.
Vagnera trifolia (L.) Morong. (*Smilacina trifolia Desf.*) Three-leaved Solomon's Seal.
Viola alsophila Greene. Marsh White Violet.

Of these the *Boehmeria, Dryopteris, Osmunda, Galium, Impatiens, Menyanthes, Comarum, Sphagnum* and *Viola* are found in the preceding list, and were common in the open marsh, the *Comarum* and *Menyanthes* in the water, the others somewhat above water level. Of the other species, the *Carices* except *C. sterilis cephalantha* are species most often found in shaded swamps, often under tamaracks, and rarely in open bogs. The *Coptis* is a northern plant, found in rich woods in New England and in the Northern Peninsula and in swamps in the more southern part of its range. The *Equisetum* and *Eriophorum* are water-loving species, usually found in the open marsh, the latter often a conspicuous species in the sedge mat, but able to persist after the Tamarack has invaded this, by keeping in the more open places.

The *Galium* and *Impatiens* are plants very widely distributed in wet places, both in the open and under shade, the latter often being the only herb in the dense shade of very wet swamps.

Leptorchis, Sarracenia and *Vagnera* are plants which are usually found in peat bogs, the *Sarracenia* as frequently, or more frequently in the open than in the shade, in fact, while it will endure partial shade for a time, as this becomes more dense it seems gradually to disappear. It is frequently found growing very abundantly in deep *Sphagnum,* but may grow to perfection in wet sedge marsh, as is shown by its occurrence in many such marshes.

The *Leptorchis,* like other members of the Orchis family, is often found in the open marsh and sometimes grows perched as an epiphyte among the culms of *Carex stricta* Lam., several inches above the water.

Vagnera trifolia is, like *Coptis,* a plant of northern range, growing generally in tamarack and cedar swamps, and while it is sometimes found growing in open places where *Sphagnum* is abundant, it is more frequent in the shade and seems to need it for its best development. The Violet mentioned, the Swamp White Violet, is common in shaded wet places of various types and will grow in shade where apparently little else is found, and where the soil is very wet at certain seasons.

Of the other plants found here, the *Sphagnum* occupied the wet places, growing in the depressions between the roots of the trees and shrubs, and often in the standing water in these. More rarely it formed very small patches above the water level but it formed at the time these studies were made, no important part of the plant covering in this area. *Spathyema foetida,* the Skunk Cabbage, was much more abundant in some parts of the tamarack growth than in others, and often covered the ground entirely with its broad leaves where the soil was wet and the shade dense. It is an abundant plant in boggy and peaty soils which do not dry out, but seems to make a good growth in the beginning only under the shade of taller vegetation, but once established, it persists as long as the drainage conditions are not improved after the removal of the shade. It may establish itself at times in open springy places, where the conditions are favorable.

After passing through the belt of Tamarack just described, a second sedge marsh is passed before reaching the original shore. This, however, is gently sloping, and the surface is covered with *Carex stricta* as the most abundant plant and as this plant grows in tufts, the culms building up dense compact stools of peat, the associated plants are perched in part upon the dryer site thus afforded. The soil here is still very wet about the roots of the *Carex* until late in the summer at least, but a number of plants found here occur in the slightly dryer types of marshes, and this would indicate that the slight slope gives some drainage. Associated with the *Carex stricta* were the following species:

Cornus stolonifera Michx. Red Osier Dogwood.
Dasiphora fruticosa (L.) Rydb. (*Potentilla fruticosa* L.) Shrubby Cinquefoil.
Rhus vernix L. Poison Sumach.
Salix Bebbiana Sarg. (*S. rostrata* Rich.) Bebb's Willow, and others.
Rubus strigosus Michx. Wild Red Raspberry.
Rosa Carolina L. Swamp Rose.

These shrubs were few in number and scattered at various distances from the margin of the swamp. The herbs were the following:

Dryopteris Thelypteris (L.) A. Gray.
Boehmeria cylindrica (L.) Willd.
Geum strictum Aiton. Avens.
Solidago Canadensis L. Canada Golden-rod.
Verbena hastata L. Blue Vervain.
Lycopus Americanus Muhl. (*L. sinuatus* Ell.) Cut-leaved Water Hoarhound.
Thalictrum purpurascens L. Purplish Meadow-Rue.
Asclepias incarnata L. Swamp Milkweed.
Aster puniceus L. Purple-stem Aster.
Eupatorium purpureum L. Joe-Pye Weed.
Calamagrostis Canadensis (Mx.) Beauv. Blue. Joint.
Iris versicolor L. Blue Flag.
Asclepias Syriaca L. (*A. Cornuti* Dec.) Common Milkweed.
Potentilla Monspeliensis L., (*P. Norvegica* L.) Rough Cinquefoil.

The appearance of *Calamagrostis Canadensis* in this area marked a definitely lower water level during the growing season in the places where it was found than do the sedges.

Returning to the sedge marsh on the lakeward side of the Tamaracks, and following around to the eastward the sedge was found to be replaced by Cat-tail, *Typha,* at the east end, except in limited areas, and there were indications that the latter was increasing the territory occupied by it, such as the presence of large numbers of young *Typha* plants among the sedge, and the close relationship of the position of the fern covered areas to that of the *Typha.* The probability that this was the case was strengthened by the fact that at Whitmore Lake within three years there has been a permanent elevation of the water level of more than a foot, and at Dead Lake a similar rise has occurred so that it is certain that one has taken place at Mud Lake, and those parts of the sedge mat which did not rise promptly with the water would become wetter than before, a condition which would favor the rapid increase of *Typha* in the vicinity of places in which it was already established. Near the Tamarack, as this part of the marsh was crossed, were a few spots where the Cassandra, *Chamaedaphne calyculata* (L.) Moench., had established itself in about the same relationship to the tamarack zone as the willows were on the south side, but it was not a marked constituent of the flora here. It was also noted that along the east end of the marsh there were numbers of young specimens of Tamarack growing with the *Typha.*

The tamarack growth surrounded the entire lake with a nearly perfect elliptical border, and as this was followed along around the east end to the north side, a very abrupt change took place in the character of the vegetation in the tamarack zone and the shrub zone immediately lakeward from it. The Tamarack became mixed with a considerable percentage of Spruce, and beneath these trees numerous shrubs occur which were not found on the south side, and the surface of the ground was covered with a heavy coating of *Sphagnum* moss. The shrub zone instead of being covered by species of *Salix* was occupied by Cassandra and other species of heaths, and extending lakeward was a dense growth of *Sphagnum* with scattering Cassandra plants, the *Sphagnum* growing sometimes in the water on the sedge mat, but not extending more than a few yards lakeward. The "islands" of fern in the sedge mat here had Cassandra and large amounts of *Typha* upon them than appeared in similar places on the south side. Considering these different associations as before, the floras of the sedge mat and the open water were practically identical to those of the south side except that *Eriophorum gracile* Koch., *Scheuchzeria palustris* L. and *Carex limosa* L. were more conspicuous, growing at the same water level with the *Carex filiformis.*

The plants characteristic of the fern islands upon the south side, here made a more definite zone, which in places was well marked a short distance lakeward of the shrub zone, which invaded it at intervals; the *Sphagnum* also often apparently found favorable conditions for growth here.

The shrub zone was, as has already been stated, characterized by Cassandra, but there were other interesting species, some of which give evidence that the marsh had not long been in possession of the shrubs. Such were:

Carex filiformis L.
Carex limosa L.
Dulichium arundinaceum (L.) Britt. (*D. spathaceum* Pers.)
Comarum palustre (L.) Marsh.
Decodon verticillatus (L.) Ell.
Eriophorum gracile Koch.
Eriophorum polystachyon L.

which were usually missing where the Cassandra was dense. The shrubby plants in this outlying Cassandra zone were few, the Cassandra constituting the great bulk of individuals, and being the most conspicuous as well, but frequently either mixed with it or in nearly pure growth, was found the Andromeda, *Andromeda Polifolia* L. (L.) Britt., while the cranberries *Oxycoccus Oxycoccus* (L.) McM. and *Oxycoccus macrocarpus* (Ait.) Pers. were noticeable upon the surface of the Sphagnum, sometimes on the lakeward side of the zone forming dense mats of their delicate vines, but they also were present among the Cassandra bushes. Here also were occasional specimens of *Sarracenia* and of various species of orchids, but none of these were important members of this association. The zone was broken for short intervals here and there by depressions below the water level, and in and around these various plants of the lakeward zones persist. An indication of the future development of the plant growth was found in the numbers of small seedlings and young specimens of the Tamarack which were to be seen among the Cassandra plants and upon the Sphagnum.

The Cassandra in much of this zone was nearly buried by the upward growth of the Sphagnum around its stems, which seemed to serve as supports for the moss. The main root system of the shrub and its underground propagating shoots were often two feet below the surface of the Sphagnum, and practically below the level of the ground water during most seasons, but as the Sphagnum surrounds the stems of the shrub, adventitious roots are developed, which, if they serve no other purpose, must increase the supply of air taken in by the plant. It is evident from this relationship of the Cassandra and the Sphagnum that the shrub must establish itself as soon as the moss or before it, since the root system is at the very bottom, and often below the moss formed peat, and a section of the bog here shows that immediately below the layer of shrub remains the characteristic structures of the sedge mat are to be easily identified.

The width of this zone, including the fern association, was only two or three rods over a large part of its length, which was an eighth of a mile or more, and it was narrower than this in places. It was bounded on the shoreward side by the tamarack zone here composed of both Tamarack and Black Spruce, *Picea brevifolia* Peck, which, as indicated above, is a very different formation from that found on the south side of the lake. Here the trees were very densely crowded in some places and scattered in others, but immediately along the border of the zone they were generally dense.

At the east end was a portion of the zone with trees which are 10 to 15 feet high, mostly Tamarack, with dead and dying Cassandra under them, the dead plants easily recognizable by their well-preserved stems.

A short distance shoreward (north) of this area was the beginning of a wide Sphagnum-Cassandra bog, which is described below.

Continuing west in the tamarack zone, from the part just described, the trees were taller and more dense, and the following plants are found growing in their shade:

Vaccinium corymbosum L. Swamp Blueberry.
Ilicioides mucronata (L.) Britton. (*Nemopanthes fascicularis* Raf.) Mountain Holly.
Aronia nigra (Willd.) Britt. (*Pyrus arbutifolia melanocarpa* Mx.) Chokeberry.
Gaylussacia resinosa (Ait.) T. & G.
Oxycoccus Oxycoccus (L.) MacM.
Oxycoccus macrocarpus (Ait.) Pers.
Rhus vernix L.
Chamaedaphne calyculata (L.) Moench. (Seldom.)
Ilex verticillata (L.) A. Gray. Winterberry.

The herbs include:

Menyanthes trifoliata L. (In wet places.)
Sphagnum.
Cypripedium acaule Ait. Stemless Ladies' Slipper.
Vagnera trifolia (L.) Morong.
Carex pauciflora Lightfoot. Few-flowered sedge and other species.
Dryopteris Thelypteris (L.) A. Gray.
Woodwardia Virginica (L.) J. E. Smith. Virginia Chain-fern.

Other species occurred, but so sparsely in the shade that they need no mention here. An interesting species, common here, is *Monotropa uniflora* L., the Corpse plant or Indian Pipe, whose saprophytic habits render it indifferent to shade.

A study of the substratum of peat in this area showed that below the Sphagnum was a stratum of woody remains and the roots of the shrubs and trees, which was about a foot thick, the lower parts of this being poorly decomposed and easily recognizable as shrub remains. There had apparently been some sinking of these upper layers of peat, for the bottom of the woody zone was, so far as could be determined, several inches below the level at which shrubs are recognizable on the lakeward zone, while the water level stands at about the same distance from the surface at any given time. Below the stratum of woody remains, at a depth of less than two feet, the top of the sedge stratum was reached, containing the characteristic and well-preserved parts of the rootstocks of *Carex* and the other plants of the sedge mat.

Following along to the west in the tamarack zone or along the marsh, about half way down the north side of the lake, the Cassandra zone was abruptly displayed by *Typha*. The Tamarack persisted in a narrow zone, but the *Typha* passed through and behind it, while from 50 to 100 feet lakeward in the *Typha* marsh were numerous young Tamaracks a few feet high. Shoreward of the Tamarack was a rather dense growth of Willows, Poplars, much *Rhus vernix* L., *Rubus strigosus* Mx. and a few young Elms, *Ulmus Americana* L., White Ashes, *Fraxinus Americana L.*, and Red Maples, *Acer rubum* L. The Sphagnum became very rare, as did the low shrubs, which, until this place was reached, had been very abundant, while *Vaccinium corymbosum* L., the Blueberry, which had been a characteristic plant, disappeared entirely. There were numerous hollows, in which water stood, and the shrubs and trees were all on the low hummocks which covered the ground between these. The shade of the woody plants was so dense that there were few herbs to be found, and the few that were present were unimportant as constituents of the association. The numerous dead tamarack poles, and the peculiarly sharp transition from one type of vegetation to the other, as well as the peculiar association of plants which existed, all pointed to some sudden and violent change of conditions, by which not only was the old vegetation entirely destroyed, but the soil and soil water relations so changed that the area could not be restocked from the unaffected part to the east, before the plants from higher ground came in and occupied the vacant space. The indications all pointed to severe fire during some dry period at no very remote date, as the agency most likely to have caused such a wholesale change and the fire marks on the tamarack stumps were additional evidence in this direction. The fire not only killed and removed the vegetation but also burned off the loose layers of vegetable débris from the top of the peat, and improved its mechanical and chemical composition and thus fitted it for the types of plants which now occupy it, but this very removal of the surface material brought the surface so much nearer the water level that the *Typha* was able to invade the area, and if any prolonged period of high water occurs the new association of plants will be destroyed and the former will then be able to close in again. This was already indicated by the presence, in the Typha marsh on the lakeward side, of young Tamaracks and patches of Cassandra, which were not losing ground in this situation.

At the west end of the lake was a sedge bog, apparently a floating mat, with *Carex filiformis* L. as the dominant plant. Shoreward were abundant *Typha* plants and many Tamaracks from 5 to 10 feet high were scattered over it.

Returning to the eastward, beyond the path of the old fire, and crossing the bog towards the north, an open Cassandra-Sphagnum tract was found. Here the principal plants were the shrubs, Cassandra and Andromeda, but Tamaracks and Black Spruces were scattered over the bog in considerable and increasing numbers, as was shown by the numerous young individuals. In addition to the trees, there were several species of tall shrubs which formed a dense growth around the borders of the Cassandra and were spreading rapidly into and over it, as could be seen in many places where the lower shrubs were already dead under the taller ones. The plants growing here were:

Vaccinium corymbosum L. Swamp Blueberry.
Vaccinium Canadense Richards. Canada Blueberry.
Vaccinium Pennsylvanicum Lam. Dwarf Blueberry.
Andromeda Polifolia L. Andromeda.
Kalmia glauca Ait. Pale Laurel. (Rare.)
Gaylussacia resinosa (Ait.) T. & G.
Ilicioides mucronata (L.) Britton. (Border.)
Aronia nigra (Willd.) Britton. (Border.)
Oxycoccus Oxycoccus (L.) McM.

Oxycoccus macrocarpus (Ait.) Pers.
Populus tremuloides Michx. American Aspen.
Picea brevifolia Peck.
Larix laricina (DuRoi) Koch.
Carex pauciflora Lightfoot.
Carex oligosperma Michx. Few-seeded Sedge.
Eriophorum vaginatum L. Sheathed Cotton-grass.
Eriophorum Virginicum L. Virginia Cotton-grass.
Scheuchzeria palustris L.
Sarracenia purpurea L.
Monotropa uniflora L.
Sphagnum.
Polytrichum.

Charred stumps and other remains of trees, mostly Tamaracks, showed that here again fire had been instrumental in removing the older vegetation, and in bringing about a renewal of former conditions by letting in the light and lowering the level of the ground.

Here, as in the Sphagnum-Cassandra zone, the Sphagnum nearly buried the shrubs Cassandra and Andromeda, but where the former was very dense, the moss does not persist, and the same was true of it under the young Spruces, where it was entirely absent in many cases but went on growing upward around the circle formed by the branches of the trees until it built up for 18 or 20 inches with a steep slope on the side under the trees, where the surface was often more than a foot lower than that outside. These banks of Sphagnum were commonly covered with the vines of the Cranberries and with Andromeda, and less frequently *Sarracenia, Cypripedium acaule* Ait., *Monotropa uniflora* L., and young Spruces grew upon them. The water level, in early summer, was above the level of the lowest parts of this area, above that in which the roots of the shrubs lie, but in dry times it gets considerably lower. At this place the indications were that the Sphagnum has built up as high as it can, when it has reached a height of about two feet above the ground water level, and in a few cases it was found that upon the top of partially dead mounds of Sphagnum, another moss, Polytrichum, had established itself. This is a dry ground type and seemed to thrive in this place, as it does upon the surface of more thoroughly decomposed peat. The fate of this Cassandra-Sphagnum bog was plainly to be read by a brief study of the area which lay between it and the higher ground to the north, for in passing across this, the margin around the bog was covered with dense growth of taller shrubs, *Vaccinium corymbosum* L., *Aronia nigra* (Willd.) Britt., *Ilicioides mucronata* (L.) Britt. and *Ilex verticillata* (L.) A. Gray. Of these, the *Aronia nigra* (Willd.) Britt., the Chokeberry, is particularly aggressive in occupying new ground or that occupied by lower plants, for it sends out long underground stems, which in turn develop vertical leafy branches, which grow up through the moss and Cassandra thickets, and, overtopping them, soon destroy them. In parts of the area to the north of the Cassandra bog, there were remnants of an old Tamarack growth under which were tall mature shrubs of most of the species mentioned above, forming a sufficiently dense shade to keep most of the ground bare except for mosses and some few small herbs. Among the Tamaracks there were also good sized trees of *Betula lutea* Michx. f., and less frequently *Acer rubrum* L. and *Populus tremuloides* Michx. In the lighter and more open places here, the following herbaceous plants were found:

Aralia nudicaulis L. Wild Sarsaparilla.
Cypripedium acaule Ait.
Unifolium Canadense (Desf.) Greene.
Woodwardia Virginica (L.) J. E. S.
Sphagnum. (In lowest wet places, in best light.)
Carex canescens L. Silvery Sedge.
Carex trisperma Dewey. Three-seeded Sedge.
Pteridium aquilinum (L.) Kuhn. (*Pteris aquilina* L.) Common Brake.
Coptis trifolia (L.) Salisb.

In addition to the shrubs, young specimens of *Betula lutea* Michx f. and *Acer rubrum* L. were common.

The peat here was of a granular structure near the surface, and is reddish brown in color. In early summer, the water stands near or at the surface of the low places and unless the season is very dry, does not get very low at any time. The top layers of peat were composed of the remains of branches, and other woody parts of trees and shrubs, with well-marked layers of leaf remains intermixed, extending down a foot or more from the surface. This layer was compact, and filled for several inches with the living roots of the trees and was coarsely granular in structure.

The peat in the Cassandra zone was much less granular, was softer and wetter, and was made up of the easily identified remains of Sphagnum for about a foot or a foot and one-half from the lowest places upon the surface. Below this was a thin stratum of shrub remains, characterized by well-preserved branches and stems of the shrubs, and under this within two feet of the surface, where the tests were made, the sedge turf was reached and abundant root-stocks and other parts of the *Carex* and accompanying plants were present and were brought to the surface.

Bordering upon this region of mature Tamaracks and covering a large part of the shoreward residue of the swamp, was a very dense growth of Poplars and Willows, interrupted frequently by shallow pools of small extent. These pools were bordered by *Typha,* various species of *Carex* and often by the low growing shrub Willows. Everywhere through this area were found the scorched remains of Tamaracks and Spruces, in many places the stumps with the roots almost entirely exposed, showing a considerable lowering of the surface level of the peat. It was evident that here again fire had changed the conditions, modified the structure of the soil and lowered its surface, and the present plant growth was of very recent origin. The presence of young Tamaracks under the Poplars was an indication that a new cycle has begun, which may eventually restore the Tamarack to its dominant position.

At the outer edge of the north side was a well-marked fosse, or marginal ditch—an open space usually covered with water from 1 to 2 feet deep, and supporting a dense growth of *Carex riparia* W. Curtis and *Typha*.

This sort of depression is nearly always present about the margins of peat deposits of this type, often extending entirely around them, and is generally wholly or partly filled with water, at least in wet seasons, and has an association of plants similar to that found here, the list of which might be considerably extended.

Similar phenomena have been discussed by McMillan,[1] who attributes the formation of Sphagnum atolls to "a season of gradual recession of the waters, followed by a season of comparatively rapid increase in area and level." Atkinson[2] attributes this ditch to the rapid and luxuriant growth of the original plants which establish themselves three or four meters from the shore and build up a deposit, from which the filling begins to work lakeward, "shutting off the shallower water near the shore from the deeper water of the pond."

In the numerous examples of this part of swamps and bogs of Michigan examined by the writer, it has seemed that the efficient cause in their production was the fluctuation of the water level through rather brief intervals and the constant recurrence of such fluctuations. These, as has already been pointed out, are attendant upon the variations in the rainfall, and the water level in the lakes, and depressions, may vary one, two, or more, feet every few years, and may remain at the low water stage for several years in succession, as has been shown is the case at Whitmore Lake, where the low water period was sufficiently long to enable young Red Cedar (*Juniperus Virginiana* L.) trees to establish themselves and reach a height of several feet on the abandoned lake bottom, before the water rose again. A similar drop in the water level took place at Rock and Bass Lakes in Montcalm county, the water being over two feet lower in 1894-1897 than in 1904. In like manner many shallow depressions which have been under cultivation during dry periods are, at the present writing, ponds. It is also a matter of observation that, during dry times, the water does disappear from these marginal ditches for long periods during the summer and fall, the bottoms becoming quite dry and this has the effect of destroying much of the hydrophytic vegetation which has established itself and also of thoroughly decomposing and disintegrating the organic matter which has accumulated during periods of high water, thus lowering the surface below that of the area directly above the zone of permanent water, which, being covered by a thicker layer of vegetable débris, is kept wet by the upward capillary movement of the water from below its surface.

Besides Mud Lake, a considerable number of other lakes were visited in which the sedge, *Typha* or similar floating mats were present, and in each of these practically the same plants were found. An interesting variant from the mat described above is that at Frain's Lakes, in Secs. 9 and 10, Superior township, Washtenaw county (Tp. 2 S., R. 7 E.) at a small pond on secton 11, Northfield township, Washtenaw county (T. 1 S., R. 6 E.), at Long's Lake, Davison township, Genesee county (T. 7 N., R. 8 E.), and in parts of other lakes visited, in which the plant making the advance from the margin was *Decodon verticillatus* (L.) Ell., mentioned as occurring at Mud Lake rather rarely. This made dense borders around the entire body of water on the two last lakes cited above, and was present upon the entire front of the advancing mat at Frain's Lakes. This plant is capable of forming masses of stems which bend over and root at the tips, at the same time making rather dense shade. The stools which they form are slightly higher than the water surface and such plants as can endure the shade and water, associated with the *Decodon* by establishing themselves upon these stools, and following in behind the advance of the *Decodon,* the sedges or *Typha* occupy the surface of the deposit. The *Decodon* stems die down each year and the advance of the plants at Frain's Lakes could be demonstrated by the existence of a number of concentric lines in the sedge mat, parallel to the present shore, in which there were a few plants of *Decodon,* less thrifty and smaller than those at the present water margin.[1] At Frain's Lakes the filling was in the middle of a long narrow depression, the mat having apparently built out from the north shore towards the south for a portion of the length of the valley and the rest of it, except at the east end of the east lake, is practically without any peat. The filled portion of the valley is nearly a fourth of a mile long and is, much of it, still covered by floating mat, through the lowest part of which is a channel connecting the two lakes.

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[1] McMillan, C., Geol. & Nat. Hist. Surv. of Minn. Bull. 9, Part 1, p. 13. Minneapolis, 1894.
[2] Atkinson, G. F., Op. cit. p. 389.

Lakes with sedge mats are illustrated by the south shore of Half Moon Lake, in Gratiot county, by numerous examples in Livingston, Washtenaw, Isabella, Oakland and Ingham counties. In Roscommon and Wexford counties the localities visited were depressions which had been completely closed in, and, while it was apparent that the same plants as those noted in Mud Lake were present and had been actively engaged in the process of filling, the advanced stage of the deposits made the exact steps of the process not so apparent.

The Water Plants and Sedge in Relation to the Peat.

If the sedge or Typha mat, as long as it is afloat, does not support any considerable number of other species of plants than those making it, and these are superficial upon the surface of the mat, and if the peat is gradually built up under the mat until this no longer floats, it is evident that the sedge must be considered as the chief agent in filling in the space between the under surface of the mat and the top of whatever deposit the water plants and other agencies have formed below, unless a circulation of water below the mat brings in and deposits débris formed outside its edge. This hardly seems probable to the writer, but his investigation has not gone so far as to lead to a final conclusion. Until such a conclusion is arrived at the alternative that the completion of the filling of the area under the mat is due in part to thickening of the mat, and, in part, to material which falls from the under side of it while it is being thickened by the growth of sedge above, must be accepted.

The final stage in the filling of deep depressions is reached when the mat closes over the water surface entirely, and the water below is so filled with peat that the entire surface becomes firm. After this the surface is built up above the water level by succeeding plant societies which are represented in the zones at Mud Lake.

After the water of the entire lake has been covered it is usually difficult to determine whether the method here described has been that by which it was accomplished or not, but if soundings show the basin to be a deep one, a vertical section will usually give proof that the sedge has been a chief factor in the later stages of lake destruction.

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[1] For a further discussion of the importance of this plant in peat formation, see the account in Part II. of this Report.

Following the time when sedges or other advancing plants have closed in over the surface of the open water of a lake or pond, however, the mat slowly thickens, as has already been pointed out, both by the building up of the surface, through the accumulation of vegetable débris and by the sinking of the mat, partly through the replacement of air and other gases held in the plant tissues by the water, water-logging, but more because of the increased load upon the surface, after the heavier tree associations become established. This sinking is, however, a slow process, and only goes so far as is necessary to establish equilibrium, i. e., until the mat is built up sufficiently to sustain the weight upon it. The thickness of this mat, even at its maximum development, is small relative to the entire depth of the deposit, rarely more than 3 or 4 feet, and in but a single case in the series examined, showing as much as 6 feet of material, which could be considered true mat, before the fluid, or semi-fluid, structureless peat below the mat was reached.

In considering the phenomenon of the thickening of the mat in this type of peat deposits, it is probable that in some cases there has been a gradual and permanent elevation of the water level, amounting to a foot or more, due to interference with the drainage from the basin, as the mat covers more and more of the water contained within it, and a lessened evaporation from the surface as the area of open water becomes more and more contracted by the growth of the mat. This interference with the drainage can readily be seen in most lakes with outlets, which are partly covered by sedge mats, but the difficulties in the way of securing absolute confirmation of the effects of such interference on the water-level, are such that none can be presented here.

Another factor to be considered in accounting for the thickening of these structures is the periodic elevation of the water surface due to cycles of increased rainfall, during which, for longer or shorter times the ground water level is raised, together with that of lakes, as has been pointed out in another place. While the floating mat undoubtedly rises with the water level to a considerable extent, there are parts of it which do not respond quickly to changes of level, and upon these the water is increased in depth in times of high water, so that water plants may establish themselves, and the plants already present may grow above the level at which they did before the rise occurred, thus increasing the thickness of the mat by adding to its upper layers new strata of rootstocks and roots.

It seems to be generally true, however, that whether the water has risen over the mat, or the mat has sunk below the water, the changes have gone on very slowly, often at about the rate at which the surface of the mat has been built up, since sections of these thickened surface structures show that during a large part of their history the plants forming them have been those which thrive either at or just below the water level.

The fact that many of the apparently filled lakes of Michigan have been covered by such thickened mats as those described above, rather than filled, has been discovered, to their great cost and embarrassment, by the railroads of the state and the engineers in charge of their construction and maintenance. The level, comparatively open surface of such bogs, as well as the apparent stability of the substratum offer special attractions for laying out railroad lines, which have often been irresistible to locating engineers. Apparently the errors have come from false estimates of the solidity and stability of the peat, gained by the use of inefficient sounding tools in the preliminary tests made to estimate the depth and stability of the substratum, for these tools will give samples which are very deceptive, since they generally show solid peat from all depths if they pass through a few feet of it, near the top of a deposit, bringing nothing from the fluid mass below.

This relatively thin covering stratum, usually only 3 or 4 feet thick, for a time after the line has been constructed, has borne the additional weight of grade and track and has endured the traffic, but sooner or later the track has sunk under an unusual load imposed upon it, by the passage of a heavily loaded train, or has persistently moved from its proper alignment under stress of continued use, because of the unstability of the peat substratum. Such bogs have given much trouble along the lines of the Pere Marquette, Ann Arbor, Michigan Central, Grand Trunk and other railroads in various places, and in the Northern Peninsula are still causing more or less anxiety along the lines of some of the more recently built roads.

A case notable in the annals of railroad engineering is described by Waterbury,[1] from whose paper the accompanying facts and Figs. 5 to 8 have been taken.

The road was originally built with a single track, and a large amount of timber was used to form a foundation for the roadbed, which was built above it. This is shown in Fig. 5. For a considerable time this single track was sufficient for the needs of the road, and little difficulty was experienced from the instability of the substratum until 1902, the track was doubled. In the process of this work "the dirt, which was dumped by the side of the existing embankment, gradually sunk

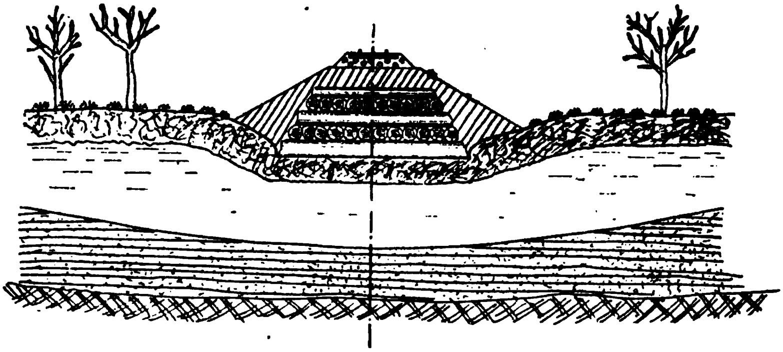

FIG. 5. Cross section showing original construction of Grand Trunk railway upon floating mat of a bog near Lansing. (Waterbury).

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[1] Waterbury, L. E., Haslett Park sink-hole on the Grand Trunk Railway. The Michigan Engineer 1903, p. 38.

out of sight, leaving a pond of water, at the same time forcing the track and right-of-way fences out of line." (Fig. 6.)

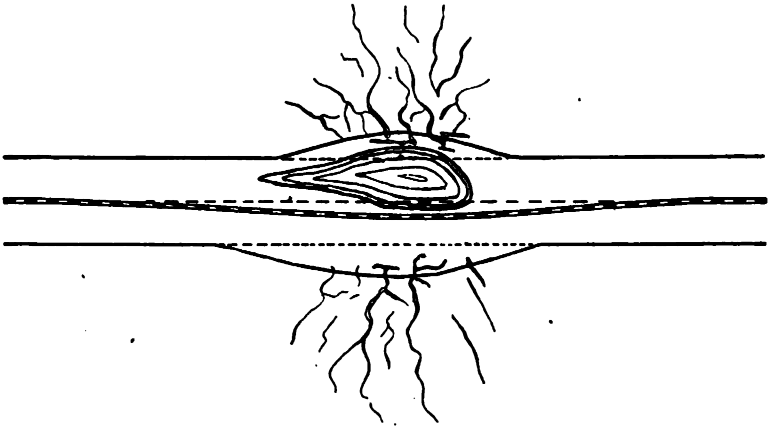

FIG. 6. Sketch map showing distortion in alignment, and cracks at sides. The dotted lines show the original positions of the fences and tracks.

The displacement of the fence was 38 feet from its original position, and of the track more than 19½ feet. The weight of the material for widening the old embankment broke the mat, carried down with it a portion of the old filling as well as the peat below it, so that the track sank whenever trains passed, sometimes a half foot, and this would have to be raised by filling before the track could be used again. In filling the opening permanently about 30,000 cubic yards of material were used before the track stopped sinking. (Fig. 7.)

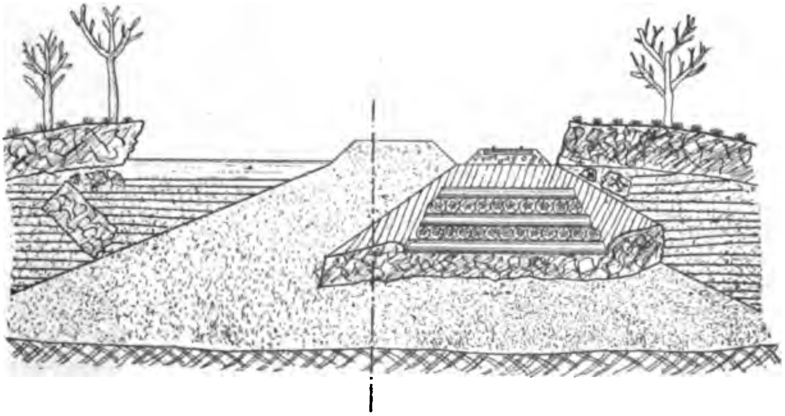

FIG. 7. Cross section, showing the displacement of the original embankment and of the floating mat, by filling for the double track.

In this figure also is shown the peculiar rising up of the mat, which amounted to at least 6 feet, caused by the displacement of water and soft peat below it, by the material used for filling.

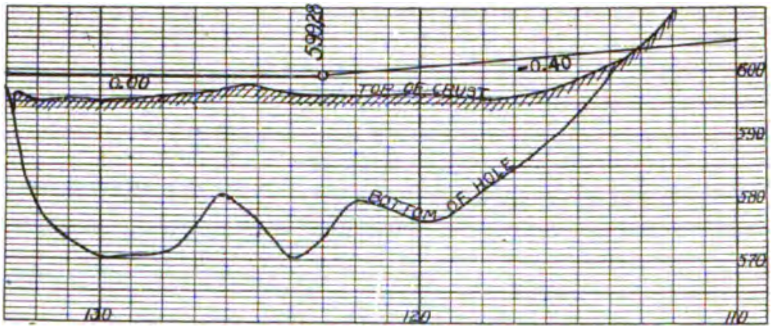

FIG. 8. Profile of a section of the bog along the line of the track. Figures on the right, elevation above the sea level.

In Fig. 8 is shown a profile of a section of the bog along the line of the track, the greatest depth being about 28 feet. In another, larger bog, on the line of the same railway, and less than 6 miles from the one described, there were used more than 60,000 cubic yards of filling in making the changes from single to double track. This depression was 55 feet deep.

The bog at Haslett Park was visited by the writer in June, 1905, and while considerable change had taken place in the vicinity of the sink-hole as described above, the elevated portions of the mat were still 4 feet above the water level, the shrinkage being in part due, in all probability, to the drying of the peat and to a certain extent, also, to changes of water level.

The surface of the bog was covered by the remnants of a forest of broad-leaved trees, mixed, in places, with *Larix laricina* (Du Roi) Koch, Tamarack, especially near the place where the sinking of the track had occurred. The following broad-leaved species of trees and shrubs were noted here:

Ulmus Americana L. White Elm.
Quercus macrocarpa Michx. Bur Oak.
Quercus platanoides (Lam.) Sudw. Swamp White Oak.
Quercus rubra L. Red Oak.
Acer rubrum L. Red Maple.

and a few other species forming a partly cleared zone around the shoreward margin. In a somewhat more open area extending from the edge of this to the sink-hole were scattered young specimens of some of these species, together with larger and more mature ones of:

Larix laricina (Du Roi) Koch. Tamarack.
Populus tremuloides Michx. Common Aspen or Poplar.
Salix nigra Marsh. Black Willow.
Betula lutea Michx. Yellow Birch.
Fraxinus nigra Marsh. Black Ash.

As undergrowth appeared the shrubs:
Corylus Americana Walt. Hazelnut.
Rhus Vernix L. Poison Sumach.
Betula pumila L. Dwarf Birch.
Aronia nigra (Willd.) Britt. Choke-berry.
Rosa Carolina L. Swamp Wild Rose.

Sphagnum was found covering small areas north of the right of way of the railroad and, in spots along the recently made cut through the raised portion of the mat. Sphagnum peat formed hummocks from 1 to 3 feet high above the general surface. A section through one of these gave the following results:

Living *Sphagnum*		6 in.
Light colored, poorly decomposed moss peat with remains of shrubs and other plants	2 ft.	
Light colored moss peat with abundant rootstocks of *Dryopteris Thelypteris* (L.) A. Gray. Marsh Shield-fern		3 in.
Below which was:		
Coarse brown peat with tree roots and stumps	2 ft.	6 in.
Shrub remains		2 in.
Finer and darker peat with sedge remains abundant	2 ft.	

In a section through the most elevated part of the upturned mat, where there was no *Sphagnum,* measured from the top to a distance of a foot below the water level, the following strata could easily be made out:

Surface litter		6 in.
Brown, coarse, poorly decomposed peat filled with tree roots and occasionally stumps	2 ft.	3 in.
Shrub remains		3 in.
More compact darker peat with rootstocks of the Marsh Shield-fern abundant		2 in.
Fine grained, dark colored peat, without remains of woody plants, but quantities of sedge and Bulrush fragments	2 ft.	6 in.

In some parts of the cut, layers of charcoal, the evidence of former fires were noted from 1 to 2 feet below the surface of the pushed up portion of the bog. The thin strata between the shrub and sedge remains, which had masses of the characteristic and easily identified underground stems of *Dryopteris Thelypteris,* the Marsh Shield-fern, were not always present, but were found in several places in the cut.

Below the stratum of sedge remains it was not easy to determine the remaining strata because of the depth of water present, but the peat was very dark colored and had little structure, although fragments of sedge leaves and rhizomes were occasionally found.

In a mass of this sort of material, probably from a lower level than any of the sections above, seen on the south side of the electric railway and at the west end of the uplift, the fine grained, structureless character was very noticeable, yet, even in this, fragments of the characteristic sedge remains could readily be made out, although not so abundant in it as in the material in the other sections.

In a second uplift, to the east of the one described, and on the south side of the Grand Trunk Railway, the elevation was a little over 4½ feet above the water with great cracks a foot or more wide, radiating from it, to the south. A section of this uplift gave the following strata from the top down:

Litter and living plants..............	4 in.
Coarse peat with tree roots............	2 ft. 6 in.
Shrub remains	6 in.
Fern rootstocks	2-4 in.
Sedge rootstocks, leaves, etc..........	1 ft. to 1 ft. 4 in.
Water-level, below which no examination was made.	

From these sections it is evident that in this instance the foundation of the mat was built up, as has been already shown, by the water-loving sedges, but that the upper portions had been formed largely by the woody plants, of which the trees, with their attendant plant associates, were the most important.

In these sections it will also be noted that the orderly succession of types, described as occurring on the surface of many similar localities, is here clearly recorded in the superposed layers of the mat which is the substratum of a mature swamp forest.

Succession of Plants Upon the Peat After the Grounding of the Sedge Mat.

There are certain types of plants which apparently are always ready to reach out from the dryer places, and establish themselves in the open areas which are offered by the surface of a peat deposit formed as indicated above, and whenever a change in the elevation of the surface takes place in any way they are quick to take advantage of it. Chief among the plants to appear upon the sedge mat, even before the surface has been raised above the water level are several species of aquatic and semi-aquatic mosses, the most noticeable ones belonging to the genus *Hypnum,* or more rarely, *Sphagnum.* On the first elevations, an inch or two above the surface of the water, the plants which appear first are principally herbs, the most conspicuous and generally distributed species being the Marsh Shield-fern, *Dryopteris Thelypteris,* which is usually accompanied by a considerable number of plants found with it at Mud Lake, all of which are more or less able to add to the deposit upon which they grow and build up the surface, when they, in turn, are displaced by more aggressive types.

The *Dryopteris* and its accompanying species not infrequently form well-marked zones where conditions are favorable, but they are more often found in patches, in places where drift material has lodged at high water, or in scattered small groups, or on hummocks formed by the stools of sedge, stems of *Typha,* etc.

The fern association was not always a noticeable element of the flora of the sedge mat, but as the same may be said of all other types as well, this is not significant.

Following the fern, the *Sphagnum* moss is often found encroaching upon the sedge, usually starting upon the fern "islands," so that where the fern association is well represented, all stages of its introduction are to be found. Sphagnum grows with erect, more or less branching stems, which crowd so closely together that they form a dense cover to the surface of the parts of the bog upon which they grow, the upper parts of the plant continuing to grow after the lower part is dead, and in favorable places they may build the surface up to a height of two feet or more, especially where they are associated with shrubs. Some species persist and even thrive when the mat is flooded by water. These mosses are so much more vigorous in their growth than the *Hypnums* that they are more easily seen and more generally known, and to them is frequently attributed the formation of all peat, in fact they are known as the "peat mosses." The *Sphagnums* are not invariably found in Michigan in the types of swamps under discussion, in fact they rather seldom occur in places where they might be expected, less than 30 per cent of the number of lakes, marshes and bogs visited on the course of this investigation, having any *Sphagnum,* even when other bog plants were present. The order of the appearance of the *Sphagnum* is apparently invariable, so far, at least, as the species which build the abundant surface coverings of the marshes and bogs to which they give the name are concerned, for not only does it exist in the south, as illustrated by the Mud Lake and Dead Lake developments, but in Gratiot county at Half Moon Lake, Montcalm county at the west end of Bass Lake near Vestaburg, in Wexford county, in the bog near Hobart Station, and in several localities in Roscommon county, especially near Boyce Lake in Tp. 21 N., R. 3 and 4 W., it is the invariable order of succession.

The same relationship has been noted by the writer and is shown by Whitford[1] to exist in the northern part of the state on the islands in Lake Michigan and is indicated less clearly by Coulter[2] for the same region.

At about the same time, or level, at which these mosses appear, sometimes with them, sometimes by themselves, before them, certain shrubs, and a few species of trees make their advent in sufficient numbers to give character to the vegetation.

While these may appear often as scattered individuals upon the sedge mat or with the ferns, they are there simply stragglers, but at the level slightly higher than that at which the ferns are most prominent, Willows of a number of species, a variety of heath plants, the Dwarf Birch, and other shrubs, such as *Myrica Gale* L., the Sweet Gale, and *Lonicera oblongifolia* (Goldie) Hook, the Swamp Honeysuckle, become common, make good growth and often cover the surface completely. The tree species which first establishes itself is the Tamarack, which often appears as isolated individuals on the open bog in advance of other woody species, but in denser growth is apparently restricted to the same level as the shrubs or a slightly higher one.

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[1] Whitford, H. N., Bot. Gaz. 31, 1902. pp. 313-314.

[2] Coulter, S. M., An Ecological Comparison of Some Typical Swamp Areas. Rept. Mo. Bot. Gard. 15, 1904, p. 46.

Some Ecological Factors Which Control This Succession.

The plants of this association have given students of the peat bog flora much difficulty, and writers upon plant ecology have made many attempts to explain their peculiarities of structure, and to reconcile these to their habitat, but no wholly acceptable theories have yet been advanced.

The shrubs which make their appearance at the water level indicated above, have especially well-marked adaptations to reduce the transpiration of water, that is, they are xerophytes[1] or drought plants while they live under conditions where there is a large excess of water, apparently always available. Some of the adaptations found in these shrubs are thickened leaves, thick, dense cuticle, glaucous (or waxy), or, less frequently scurfy, woolly, or hairy, and, in case of *Gaylussacia,* resinous, covering for the leaves, especially on the under side and for the young twigs. The leaves are elongated or narrowly linear in form, often rolled, i. e., reduced in size, or in the case of the conifers, short needle or awl-shaped, or reduced to scales.

Schimper[2] attributes this peculiarity to impeded absorption of water by the roots, caused by the presence of humus acids in the peat. Livingston,[3] however, has pointed out that "Bog waters do not have an appreciably higher concentration of dissolved substances than do the streams and lakes of the same region," and it is therefore evident that any effects produced by the humus acids must be chemical, if they are present at all, because the osmotic effect of bog water is that of ground water generally, and will be as readily absorbed by roots.

Whitford[4] adds to the above the factor of "insufficient aeration of the soil, which prevents a healthy growth of the root system of land plants, and also bars the presence of nitrifying bacteria." Adding that "These probably bring about xerophytic structures of the plants so commonly seen in hydrophytic habitats." Cowles[5] states that N. H. Nillson attributes the differences between the hydrophytic and xerophytic swamps to differences in food supply. It has also been suggested that the differences in temperature between the water about the roots and that of the air around the foliage of the plants in the open swamps and bogs, produces a tendency to excessive transpiration accompanied by slow absorption from the soil, the roots' activity being reduced while that of the leaves is accelerated, thus producing a need of protection against the loss of water which causes the xerophytic structure mentioned.

A comparative study of the plants of this shrub society and its habitat has made the following interesting facts apparent:

1st. The area of swamps upon which these plants become dominant is fixed so that it no longer rises and falls with fluctuations of the water level of the lake, hence the water rises and falls in the peat as it does in other soils, often as much as 15 feet in peat deposits around ponds.

2nd. During periods of minimum rainfall, the water level may fall sufficiently to leave the *Sphagnum* and the upper layers of the peat very dry, sufficiently so that they will readily burn, as is shown by the extensive areas burned over at Mud Lake and in a number of other localities visited, in which from one to three feet of peat have been burned off. These dry periods may last for several years and during their continuance the habitat is actually, not potentially, very dry.

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[1] Schimper, Op. cit. pp. 3-17.

[2] Schimper, A. F. W., Op. cit., pp. 4 and 111.

[3] Livingston, B. E., Bot. Gaz. 37 : 383-385, May 1904.

[4] Whitford, H. N., Op. cit. p. 314, 315.

[5] Cowles, Loc. cit. pp. 75-76.

3rd. From peat, unless thoroughly decomposed, because of its mechanical structure, it is difficult to extract water by any means except heat, the water being held in the cell and vessel cavities of the partially disintegrated vegetable matter so firmly that the strongest pressure will not force it out, beyond a certain limited amount, and centrifugal force is equally ineffective.

These facts have been established by experiments in attempting to prepare peat for fuel without heat, and make it apparent that plants growing with their roots in peat in which the water content does not approach saturation will have difficulty in extracting sufficient for their needs. In other words, peat above the water level is structurally a very dry soil. Moreover, when it is once thoroughly dry, or even only air dry, peat does not readily absorb more than a small per cent of water, and a block of the material may be exposed for days to water without becoming wet through, because certain soluble matters in it become colloidal in drying and form a nearly insoluble coating in the outer layers. This property tends to prolong the period of drought in a bog that has been dried out.

Direct experiment with plants has demonstrated the soundness of these conclusions, for as long ago as 1875, according to Warrington,[1] Heinrich[2] reported that various crop plants required much more water when grown in peat to prevent wilting than in other kinds of soils, and that in the case of the potato the amount of water required was 41.4 per cent of the weight of moist, or 70.8 per cent of dry peat. This amount is very much greater than that required in any other soil, as is shown by the following table:

Parts of Water per 100 *of Dry Soil.*

Type of soil.	When plants wilted.	Absorbed from moist air.
Coarse sandy soil	1.5	1.15
Sandy garden soil	4.6	3.00
Fine humus sand	6.2	3.98
Sandy loam	7.8	5.74
Calcareous soil	9.8	5.20
Peat	49.7	42.30

In experimenting with crops on peaty lands, it has been demonstrated that the peat must contain more than 60 per cent of its weight of water to yield productive crops.[3] If these results are correctly reported, it appears that peat may appear very wet, and yet contain no water which is available for plants growing in it, so that those which habitually grow at levels of peat bogs where the surface strata can dry out, must have xerophytic adaptations if the climate is such that drying out of these levels may occur. These conclusions are supported, in part at least, by the testimony of many farmers in the region under discussion, who report that crop plants suffer more severely from drought during dry times on muck or peat soils than upon other types. Experiments with our native plants have been planned to test the correctness of these conclusions, but it is too early to report upon them at this time.

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[1] Warrington, R., Physical Properties of Soils, 1900, pp. 63-64.
[2] Heinrich, Jahresb. Agrik. Chem. 1875-6. p. 368.
[3] Biedermann's Central-Blatt fur Agrik. Chem. 1885, p. 279.

(4.) Not only must perennial plants endure, from time to time, the difficulties of real drought in peat bogs, but they must also be able to stand excessive wetness about their roots for long periods and the heath plants, *Betula pumila,* and several species of *Salix* and a few others are able to do this for at least three years without being injured, for the writer has had these species under observation where the water level has been raised more than a foot above its former height upon a heath bog for that length of time, and the plants still survive in a fairly good condition, while other species, more sensitive to water, have died.

(5.) In the heath zones and heath swamps of the southern part of the Southern Peninsula of Michigan there are more species of shrubs and trees near the water level than in the north, and as the surface of the peat is drained even slightly, species of plants occupy it which never, so far as observed by the writer, are found in the same sort of habitat at the north, but grow in the dryest and poorest soils there.

A most striking example of this is *Aralia hispida* Vent., which was a common species on the peat deposit at Chelsea, now being utilized for the manufacture of fuel. Proceeding northward some species leave the peat soils entirely and are only found upon dry and poor soils, while others still remain in them but only around their borders at a well-defined distance above water level, while others still are found at the water level as far north as observed. The following notes illustrate this:

Gaylussacia resinosa is common at Ann Arbor, both in and out of the bogs, growing as freely on light sand as it does in the bogs, but not so tall.

In Gratiot county it was rare in bogs, but very common in the dryest places on poor sandy soils, while in Roscommon county it was not noted at all in the swamps although very abundant as a sand plant. In Tuscola and Huron counties it occurred as a sand-dune plant. It endures shading well wherever found.

Dasiphora fruticosa (L.) Rydb., at Ann Arbor, is an occasional constituent of the open bog and marsh flora, in the heath zone, but occurs upon a very dry hillside at Lakeland and further north in Huron and Tuscola counties it was found only upon sandy shore lines; still farther north, however, it was noted in bogs, as well as on sandy soils.

Vaccinium Canadense, in the vicinity of Ann Arbor, is found usually, if not always, in the peat bogs, and in Gratiot county it is still a peat plant, but is found growing upon mineral soils in dry places as well, while in Roscommon county it is the most common sand and dry ground blueberry, covering sandy ridges and flats, wherever the ground was open enough, and was not listed from the peat bogs at all.

Vaccinium Pennsylvanicum does not occur in the lists made by the writer about Ann Arbor, except at Mud Lake, as noted above. At Alma, Gratiot county, it is found upon the dry and sandy knolls, but sometimes in the margins of swamps as well. In Roscommon county it occurs on dry sand commonly and was not noted elsewhere.

Vaccinium corymbosum. In Southern Michigan wherever found is a plant of the heath association, often in the very wet part of the swamps, and persisting after the surface gets quite dry, and also under the shade of the taller shrubs and trees. At Alma it is still a plant of the same association, and was not seen in the bogs examined farther north, but in New England it grows commonly on high and dry ground as well as in the swamps.

Aronia arbutifolia and *A. nigra* (Willd.) Britt., the latter more frequently, grow very commonly and with great luxuriance in many of the heath swamps in Washtenaw and Livingston counties. In Gratiot county the latter species occurred both in the peat and on dry sandy soils, and in Roscommon county it covered the sandy hillsides from the top down nearly to the water level, but was not recorded in the swamps, except as a straggling plant in the dryer parts.

Ilicioides mucronata (L.) Britton, is always a plant of the heath swamps about Ann Arbor, so far as observed, and is often found growing in very wet Tamarack swamps in the shade, to large size. At Alma it was not common, but grew in wet swamps where found. In Roscommon county it grew only on the borders of the bogs, often forming a distinct zone on the mineral soil on the borders of the bogs, from about a foot above the water level to 3 or 4 feet above it, starting in above the Cassandra. In Wexford county it was found growing in a rather dry and shallow peat deposit, near the margin.

Ilex verticillata is rather common in the vicinity of Ann Arbor, in the wet parts of peat swamps, often in the shade. It also grows well in other swamps and on mineral soils near the water level, where it endures the shade well. In Gratiot county it is very common in wooded and open swamps, and is not uncommon in the borders of swamps. In Roscommon county it was found mainly on the borders of the open swamps with *Ilicioides,* but was also found well distributed in the Cedar and Tamarack swamps, and was noted as growing from these up to a height of 3 or 4 feet above the water level on the mineral soil.

Cassandra, as found in the south, is always a plant of peat bogs and of the wettest parts of these, probably never establishing itself more than a foot above the water level, and has not been observed in the region of Ann Arbor, growing on mineral soil. In Gratiot and Montcalm counties it is usually found in the peat bogs, but at Bass Lake it grows well upon an ice-formed sand ridge at least three feet above the level of the lake, and shows in some of the bogs a tendency to grow above the water level.

In Roscommon county, while it makes luxuriant growth in the swamps and bogs, it seems to avoid the very lowest parts of these and is found making well-marked fringes around the wet sedge bogs extending out into these upon fallen logs and creeping up the sandy banks of the Sphagnum swamps, where it also covers the whole surface. It was noticed well established near Boyce Lake as much as 4 feet above the water level, growing in sand, and mixing with the Sweet Fern, which covered the higher parts of the slopes.

Kalmia glauca Ait. is a rather common plant in the region studied and associated closely with Cassandra, but was not seen outside the bogs.

Andromeda Polifolia L. is found at Ann Arbor in the wet part of the heath zone, and as far as studied shows no indication of leaving the water level or of growing in mineral soil, for in Roscommon and Wexford counties it was always found as far out in the sedge zone as any shrubby plant.

Betula pumila L., as it occurs about Ann Arbor, is common in the wet parts of the swamps and marshes in which it occurs, but persists after the water level has been lowered by draining and in a single case has been found in a moderately dry situation growing in mineral soil, at least three feet above the water level. Farther north it keeps in the peat bogs in the very wet places and does not get above the water level.

Myrica Gale L. was only found in Roscommon county growing in the wet zones of the marshes and bogs with the sedges. Farther north, however, it was seen frequently in sandy soil above the water level.

Ledum Groenlandicum Oeder, the Labrador Tea, was another species found only in the northern part of the region studied. In Hobart bog it was growing in the higher levels of the Sphagnum zone and in the tree zone, where it bore the shade well. In the vicinity of Boyce Lake it was apparently more plentiful in shade than in the open, and grew in the better drained situations slightly above the water level and sometimes in mineral soil.

Salix myrtilloides L. and *S. candida* Fl., the most interesting of the various Willows which grow in the heath swamps show little change in their relation to the water level throughout the region studied, both keeping near the water and showing no greater tendency to grow away from it at the north than at the south.

Spiraea tomentosa L., an Ann Arbor, is occasionally found growing in the peat bogs and more rarely on the wet shores of lakes, a foot or so above the level of the water. In Montcalm county this plant grows on the borders of a few bogs, but was not found growing in them. In New Hampshire the species is frequent in dry and barren pastures, where it takes the poorest and dryest places.

The Tamarack, in the region about Ann Arbor and southward, is a bog or swamp tree, seldom occurring outside of peat deposits, and usually very near the water level. It has been planted on high ground in the city and has grown well there. In Gratiot county the tree is sometimes found on high ground around swamps, while on Mackinac Island it is found growing at all elevations and in all kinds of soil, making a fairly constant element in the second growth forest.

Enough species have been cited to show the marked tendency which these bog shrubs and trees have to leave the bogs for higher ground and a type of soil where the water level is low and the soil moisture scanty, and to indicate that in the more southern part of their range plants may be confined to the bog habitat and in the northern to truly xerophytic conditions on mineral soil.

From the consideration of these facts follows the conclusion that many, if not all the "bog xerophytes" of the peat swamps of Michigan are bog plants only in the southern part of their range, and that many of their obvious adaptations for protection against drought are needed in their ordinary habitat in the region of their greatest frequency and widest dispersal and these enable them to persist in bogs and swamps during constantly recurring dry periods towards the southern limits of their range.

(6.) The plants given in the above list, many of them, have fleshy fruits, which are attractive to birds, and aid in securing the dispersal of their seeds. An observer has only to visit one of these heath swamps during the time when the various fruits are ripe to see how attractive these are in color, form and size, to the fruit-eating birds, as well as to man, for a little watching will show that more than one species is at work gathering fruit. In the late summer and early fall, the migrating season, the swamps are full of birds, and flocks of robins and blackbirds may be found at work in them at almost any time, but especially in the morning and late afternoon. In fact several species make these swamps regular migration routes as they move southward, and by them the seeds are carried from north to south each season and scattered where, if conditions are favorable, they will be most likely to germinate, namely upon thoroughly moist soil in the swamps, which keeps the seed coats, already softened by passing through the digestive system of the birds from drying again. It would seem that no other factor need be considered to account for the occurrence of the great number of shrubs which characterize the heath swamps of Michigan.

(7.) With the appearance of the shrubs and trees upon the sedge marsh, another biotic factor than tolerance of water enters into the matter of deciding what types of plants will finally occupy the ground. This is the relative need of light of the various species, or their tolerance or intolerance of shade. Those plants which live from year to year grow to different heights, and the taller ones finally overtop the shorter and unless these can endure shading they must succumb. An extended series of observations upon the woody plants growing with the *Sphagnum* upon the marshes under consideration, and others as well, establishes the fact that many of the species are unable to bear a weakened light, and as soon as shade of any density develops in their habitat, they disappear and their places are taken by species which will grow in the shade. The more aggressive species, such as *Aronia nigra,* are aided by their method of propagation, a system of long underground branches sent horizontally from the parent plant in every direction and these, at their ends and along their sides, send up vertical leaf-bearing stems which soon establish themselves and make new centers of dispersal. Such species may advance as much as six feet in a season upon any of the lower shrubs like Cassandra and in a few years after becoming established hold the entire ground. The Tamarack is taller than most of the plants with which it is associated upon the marshes, hence it shades them, and, while its shade is not dense, it seems to be effectual in stopping the growth of a number of species and finally exterminates them. Cassandra is often shaded out by the Tamarack and the only record left is that which the dead and dry stems of the lesser plant give, and the partly decayed débris in the peat below. The Blueberry, *Ilex verticillata* and *Ilicioides mucronata* on the other hand, are more tolerant and often make large growth in the shade, the last named species sometimes reaching a height of 20 feet under old Tamaracks. In like manner the Black Spruce is a taller plant than its associated species, except a few trees, and makes a denser shade than the Tamarack, and under its shade few species survive, even the *Sphagnums,* which are able to get along with less light than most of the marsh plants, give way before it. Again, the Tamarack seedlings cannot grow in the shade of the Spruce, while those of the Spruce grow readily under the Tamarack, as do those of the Cedar, so that often the Tamarack lasts but a single generation, being succeeded by the more tolerant species. The Tamarack also cannot grow up in the shade of the Red Maple and Birches and other broad leaved species and if overtopped by them at any age, is generally killed, so it gives place to these species when they succeed in establishing themselves in competition with it, and it is either driven to wetter open spots farther out upon the marsh or disappears entirely.

The Tamarack will grow under the lighter shade of Poplars and Willows, and thus may succeed a growth of these species, since they do not live when shaded by it.

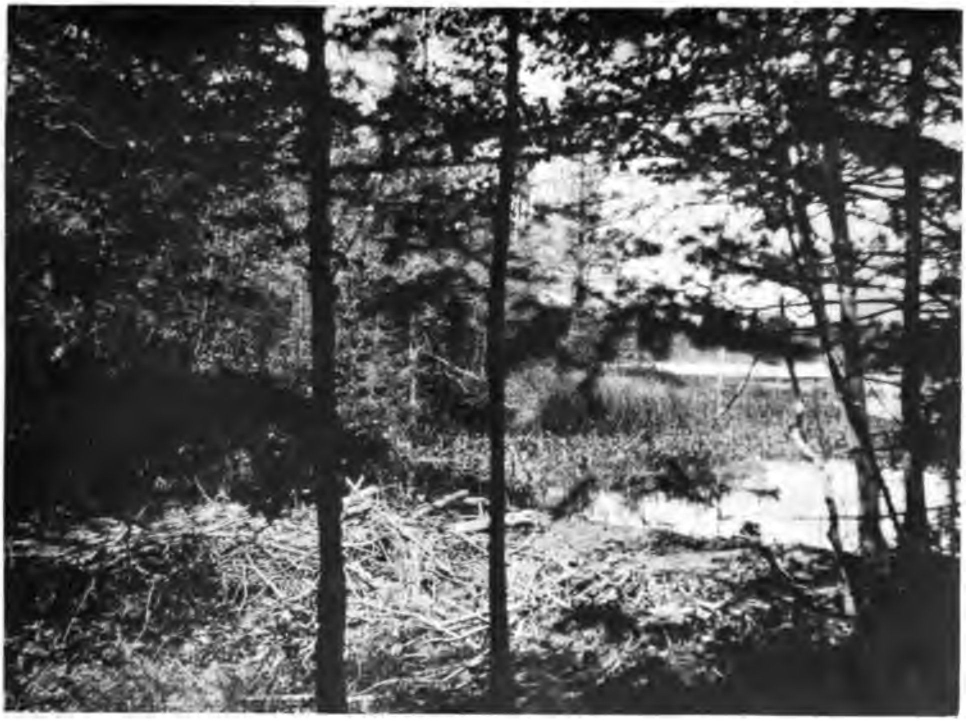
From the foregoing discussion it is evident that the plants upon the surface of a peat deposit are not necessarily nor usually an indication as to the character of the peat below, and in general are relatively a short time in places where they are found. In the filled basins, and in other types of peat deposit as well, the character of the vegetation is certain to change with fluctuations of water level, which may occur as the result either of prolonged drought, periods of less than normal rainfall, or periods of excessive precipitation, the latter being especially effective in causing change, because plants which may have been years in establishing themselves in places which they occupy, may be killed in a very short time of high water and the ground which they have been occupying thus be left free from growth of such species as are able to live under the new conditions.

A change in the elevation of the outlet of the basin, if one exists, will produce the same effects as the variations in precipitation, drying out if it is lowered, and flooding if raised.

If such an elevation of the water level is at all permanent, the whole cycle of plant growth may be passed through with again. Elevations of the water level from six inches to one foot are efficient in producing complete change in some of the swamp associations.

From the lateness of appearance of the *Sphagnum* moss upon the deposit made by the water plants and the Carices it is easy to see that no great thickness of peat is built up by it. The height to which this could go on is limited by the height to which the water level may be raised after the appearance of the moss, or that to which it will rise in the *Sphagnum* through capillary action. Under climatic conditions such as prevail in Michigan, this is about 2 feet and, unless the surface of the peat slowly settles as consolidation of the material below the surface goes on, the formation of the peat ceases, so far as *Sphagnum* is concerned, at that level. In the cases where this was tested, sections at Mud Lake, and at Oxford, Oakland county, show that in less than two feet all of the deposit which can be attributed to the moss is passed through. Above this deposit there may be as much as a foot of living moss, though usually less.

A section made near Vestaburg, Montcalm county, through an island of *Sphagnum* gave 21 inches from the top of the living moss to the bottom of the moss peat, below which were 1 to 2 inches of shrub remains, probably *Cassandra,* which was still growing in the "island."



Beaver Dam near Negaunee, Mich., shows pond and marsh along border.
Photo. by Prof. R. H. Pettit, M. A. C.

Below this were remains of sedge rootstocks and roots for an inch and at from 4 to 5 inches below the bottom of the *Sphagnum* was a well marked zone an inch or more thick with large quantities of rootstocks of the Yellow Pond Lily, with numbers of the seeds in the peat above. Below this, to the bottom of the section, the peat was more homogeneous, but was easily separable into laminae, which when split apart showed large numbers of the leaves of grass-like plants.

Similar sections through the *Sphagnum* in Roscommon county, gave similar results.

Deposits Formed Behind Dams.

In the hollows which have been formed by dams of some of the types mentioned in a former paragraph, the effects of changes of the water level are shown most clearly, as in these there may be a periodical elevation of the barrier to a greater height, and this in turn holds the water impounded back to a greater height, which at once reacts upon the vegetation and changes the type of growth more or less completely.

Beaver dams were probably the most common type of dam which resulted in the formation of peat in the region of which Michigan is a part. Speaking of them and their occurrence in the state Desor[1] says: "They cite in Michigan, rivers of considerable size which are barred by dams, making thus a quantity of lakes and ponds which would not exist without them. It is evident from this that without these dams the lake and peat deposits, which are found at the bottom of these ponds, would be less numerous. The beavers have thus exercised an influence not only on the distribution of waters, and the consequent fertility of the soil but also up to a certain point even upon the distribution of recent rock formations."

The importance of the beaver as an agent in the formation of peat in the Southern Peninsula is also mentioned at some length by Bela Hubbard,[2] of the first Survey, one of the keenest writers who has ever written upon the geology and natural history of Michigan, and even earlier geologists.

In this article the writer says: "Not one or two, but a series of such dams were constructed along each stream so that very extensive surfaces became thus covered permanently with the flood. The trees were killed and the land converted into a chain of ponds and marshes with intervening dry ridges. In time, by nature's recuperative process—the annual growth of grasses and aquatic plants—these filled with muck or peat, with occasional deposits of bog lime, and the ponds and swales became dry again.

"Illustrations of this beaver-made country are numerous enough in our immediate vicinity. In a semi-circle of 12 miles around Detroit, having the river for a base, and embracing about 100,000 acres, fully one-fifth part consists of marshy tracts or prairies, which had their origin in the work of the beaver. A little further west, nearly a whole township in Wayne county is of this character."

Taking the beaver dam as an illustration, since it is small, rarely more than 5 or 6 feet high[3] and relatively rapid in its effects, the course of development of this type of peat deposit would depend upon the following considerations.

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[1] Desor, E., La Foret Vierge, p. 57, Paris, 1879, 57.

[2] Hubbard, B., Memorials of a Half Century, pp. 362-3, N. Y., 1888.

[3] Melton and Cheadley. North West Passage by Land, p. 178.

In regions of comparative flatness, the building of even a low and weak dam, such as beavers erect, will flood a considerable area. This is clearly stated by Melton and Cheadley, who report that the former operations of beavers in Canada must have been on a very extensive scale, for nearly every stream between the Pembina and the Athabasca except the large Macleod river appeared to have been destroyed by the agency of these animals.

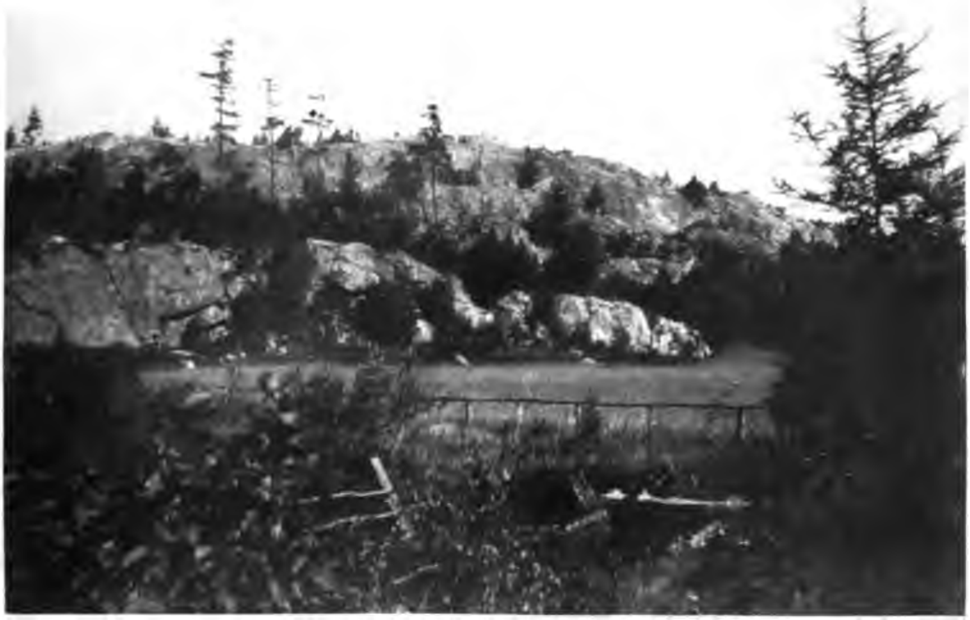
At one place they found a long chain of marshes formed by the damming up of a stream which had ceased to exist, the beaver huts had become grassy mounds and the dam a green and solid bank.

If such an area was covered at the time when the water level was raised by a growth of trees or shrubs, these would be killed, and some would be cut down by the beavers for food and construction purposes, the rest would decay and fall to the ground or into the water, where they would shortly be overgrown and buried. The destruction of this taller growth would enable the marsh plants bordering the stream and the water plants growing in it to spread out, first upon the margins of the flooded area, then because the water is shallow, over the whole impounded surface. Such an area of shallow water would fill rapidly with vegetable débris, and as reedy and grassy types of vegetation obtained a foot-hold and became abundant the water area would be restricted, until perchance, the animals built their dam higher or abandoned it for a new place.

In the former case there would be a new advance of water plants over the marsh vegetation, while in the latter, the marsh would become at first covered with stages or *Typha* and later by grasses, one of the first to be established being probably *Calamagrostis Canadensis,* the Blue Joint, of which stages, good examples are the so-called "beaver-meadows," so often utilized as sources of hay by early settlers in Michigan and other parts of North America. At the last period as the drainage improved, Willows, Alders and other shrubs would appear on the surface and finally the forest would close in again.

The fact that the original course of the stream had been obstructed by even a weak dam would tend to cause accumulations of drift material upon the obstructed area in time of floods, and eventually this might form such a check to the drainage that the water level might be raised faster than the vegetation could build up the surface. In such a case the tree growth would be destroyed, and again the area would be covered by water and marsh vegetation, to go through the cycles as before.

In undisturbed natural conditions it is probable that the beavers would occupy a favorable site again and again as the surface of the deposit was built up and their favorite food plants re-established themselves within reach from the place where a dam could be maintained, and in at least two cases which have come to the writer's notice such dams as these have been found in cutting into peat deposits. The first of these was cut through in draining a peat bog in Sec. 2, in Arcada township, Gratiot county, where the dam was buried under about three feet of peat and seemed to be about three feet high. A case of recent reoccupation of an old dam site by a colony of beavers was observed by the writer in the Northern Peninsula, where a very old dam had been rebuilt



Beaver Meadow near Negaunee, Mich. Photo. by Prof. R. H. Pettit, M. A. C.

within the present year (1906), flooding about 50 acres of Spruce and Tamarack woods.

This dam was located in section 2, T. 49 N., R. 30 W., and was about 4 feet high in the channel of the stream which was closed by it, so that the water level was raised to that extent. The outside of the dam was a tangled mass of brush, sticks and pieces of wood both freshly cut and in all stages of decay, the animals evidently using whatever material they found near the place. The top of the dam was about a foot wide and had a number of small stones placed irregularly upon it, and the water side of the structure was heavily plastered with mud.

The dam was nearly water tight, only a small amount of water running under or through it, the greater part of that which escaped from the pond was going over the ends, which were slightly lower than the middle, or over the long side wing, built to increase the height of the water by the former tenants of the dam, and repaired by the present generation. The main structure was strong enough to bear the weight of a heavy man without yielding. The dam was built across the brook where the valley was divided by a slight elevation, and after the main part was done, the builders found it necessary to construct a long wing from the elevation across a marshy place to the other wall of the valley. This wing was from 1 to 2 feet high and about 200 feet long, and the old structure completely overgrown by shrubs and other plants, was visible, having simply been repaired in the broken places and raised in the low ones, from the pond side, by the use of small sticks and mud. The repair work was apparently very frail although fairly efficient. An interesting feature of the main dam was the fact that the arc curved irregularly down the stream. Down the same valley and extending nearly up to the dam described was a broad flat swampy area covered with shrubs and sedges, with a few scattered small trees. At the lower end of this was another ancient dam completely overgrown but easily traced as a sharp ridge across the narrow part of the valley.

Since beavers have been protected by the game laws their dams are becoming common in the wilder parts of the state and around Trout Lake Junction and other places in the Northern Peninsula, the flooding of timber lands and the destruction of trees upon them as well as the interference with railroads is reported as caused by the disturbance of the established drainage by these animals.

In draining the extensive bog at Capac, near the outlet end, or the south end of the marsh, beaver dams were cut through in making the ditches which had in the uppermost 4 feet, a second 10 feet and a third 12 feet of peat over the top, while the section of the bog in the ditches, was formed of successive and superposed layers of vegetable débris showing that several times forests had been succeeded by grass or sedge marshes. In its final stage this deposit was a Cedar and Tamarack swamp, with practically no natural outlet, the water which fell upon it either draining by seepage to the Belle river or evaporating from the surface.

At present the surface of this deposit is bare of tree growth having been denuded by fire and cutting, and while both seedling poplars and certain types of bog plants are present, the most abundant plant when visited was a species of *Polytrichum*, a moss which is usually found in bogs where the surface is very dry, and which indicates the end of peat building.

In either of the cases mentioned the resulting deposits of peat would, upon careful analysis, show a definite stratification, the strata repeating themselves in an order which would give a history of the deposit, with the remains of the more completely preserved plants identifiable. In such a deposit, at the bottom, might be found the roots and stumps of trees, above which the remains of water plants would be present to some thickness, then a mass of fibrous remains of the sedge and grasses, and possibly then the débris of mosses and shrubs, and, (showing the end of the cycle) roots, trunks and other tree débris. At Capac several strata containing tree remains were seen as noted above, but the opportunity was not offered to make a more detailed study. Where such formations of peat are found they show conclusively that the conditions under which the deposits have been formed have not been constant, but have varied, and in a definite order.

Conclusion.

The foregoing discussion makes it evident that in the Southern Peninsula of Michigan, peat is chiefly formed by plants which grow below or very near the water level, aquatic plants in connection with sedges, and other grass-like plant; *Sphagnum* does not appear until late in the history of the formation, if at all, and develops only shallow, superficial layers of peat and usually grows best in association with certain shrubs, which may become prominent before the *Sphagnum* appears, and which may also reduce its effectiveness in peat forming by developing dense shade.

The ecological factors controlling the succession of plants, which by their growth and decay, under the necessary conditions, form peat in the area under consideration have been indicated, but may be summed up as follows:

(The effects of these factors on the form of organs, i. e., adaptations, is not here considered.)

Light: That which may be considered of first importance, since a wet habitat is assumed, is the light factor, because this limits the development of peat deposits through limiting the growth of plants, both below and above the water level.

Plants which make abundant vegetative growth in northern regions must have full light, and this is not obtainable in the deeper water in depressions, or in the dense shade of other species. Direct deposition by living plants therefore is limited by the depth of water through which sufficient light may penetrate to induce vigorous plant growth, or to develop such species of plants as send leaves to the surface through earlier stages of growth, before their leaves reach the surface, and by the amount of shade in which peat-forming species can develop. The water of many lakes in the northern part of the state, while free from sediments, is dark colored from dissolved organic matter, and in such lakes there is little vegetation to be found.

Soil: A second group of factors of importance are those termed the edaphic or soil factors. Both the physical and chemical characters of the substratum in which the underground parts of plants grow are important in determining their distribution, and in many cases control the type of vegetation in a given area, or account for the presence or absence of certain types.

It seems probable, from the present state of our knowledge, that many species of the important peat-forming aquatic plants are greatly dependent upon the mechanical structure, the compactness, and the penetrability for the roots of plants, soil-water, etc., as well as the chemical composition of the soil in which they grow, and it may be demonstrated that both species and individuals are much more numerous where there are beds of loose, finely divided material, rich in plant food than where the substratum is compact, hard and poor. This is in part due to the requirements of many species for abundant food, and in part to the greater ease with which the stems and roots penetrate the less compact soils; and as the stems, or rhizomes, of a large number of such plants are propagating organs, a favorable soil for the growth of these, favors the dispersal of the species over the bottom of a lake.

Temperature: Heat is a third factor of importance, and its absence tends to reduce the number of species and number and the size of individuals, therefore in the southern part of the state many more species are found in the aquatic societies than in the northern, and these are therefore more efficient in building up peat south than north, so that it may be safely assumed that the filling of lakes goes on more slowly, and is caused by fewer plant species in the north than in the south.

The facts that the mean temperature of the air is lower during the summer season, and the periods of maximum temperature are shorter and fewer, cause decreased evaporation from wet soil and from water surfaces and render these more stable as to the water level at the north. This, because of the more uniform temperature, does not fluctuate, and changes in plant associations take place more slowly and with less frequency, north than south. The result is obvious in checking the advance of the shoreward associations to regions of high water level, since they chiefly advance in periods of low water, and in the less rapid upbuilding of the surface.

The lower soil and water temperatures at the north also tend to increase the physiological dryness of the soil in the habitat under discussion, and its physical dryness, when once dry, because the greater viscosity of water at low temperatures retards percolation and thus make it increasingly difficult for species to establish themselves in it, going from south to north.

The daily fluctuations in temperature of the air in depressions, because of lack of circulation during the day, and of the downward flow of cold air during the night, is much greater than that upon the surrounding higher lands. The minimum temperature in many of these reaches the freezing point during every month in the growing season, even in the southern part of the Southern Peninsula and this fact alone affects the composition of the associations above the sedge zone to a very considerable extent, keeping out southern plants which would otherwise establish themselves. The species near the open water of partly filled lakes or growing in it, on the other hand, probably are favored by an even temperature, and a somewhat prolonged growing season.

Air: The difficulty of getting a sufficient supply of air from soil saturated with water or from water directly, excludes from the plant associations concerned in peat formation, all plants which do not have special adaptations or cannot develop them, for the purpose of getting oxygen under the conditions presented. This limits the number of species which grow in the water, and with roots below the water level, to a few, and reduces the competition between types and species to a minimum, thus favoring good development of the types which can live under the conditions. Above the water level this factor still has its influence in excluding species which are deep rooted in favor of those which are shallow rooted, thus again reducing competition and simplifying the associations.

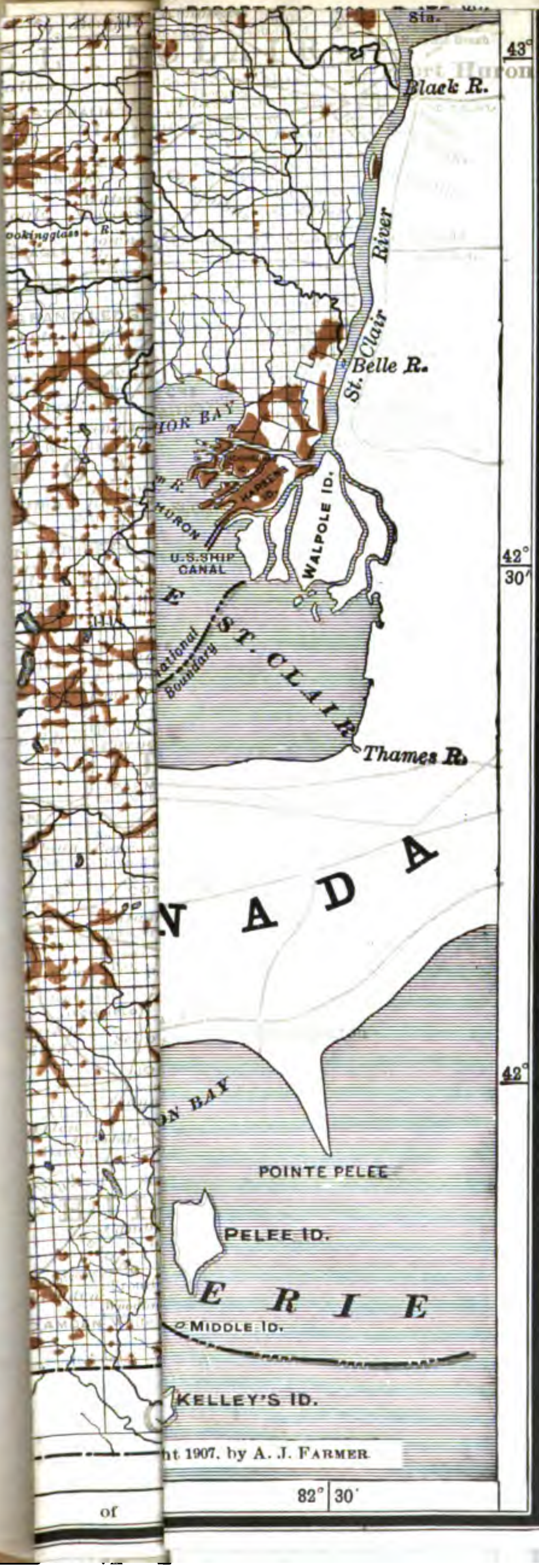
The other important influence of air which may be considered is in its effects as wind. In the wide stretches of open marsh or bog, plants are freely swept by winds both winter and summer, and transpiration is greatly increased thereby, a fact which again influences the composition of the plant associations growing in peat deposits with leaves exposed to the air, those which are not protected against excessive transpiration being excluded in favor of those which are, and again the composition of the associations may be simplified in number of species by this factor.

The wind, on either hand, has a profound influence in aiding in the distribution of most aquatic plants along the shores of the bodies of water in which they grow and a great many of the species of this type are provided with adaptations which insure the transportation of propagating buds, fruits and seeds from one point to another by wind and currents created by winds, and the leeward side, which is frequently the eastward one, of any body of water in which plants are growing will give numbers of illustrations of the importance of this factor.

Plants: After the length to which the subject has already been discussed it is scarcely necessary to do more than mention that the influence of most species of plants upon some of those with which they are associated is important, in a greater or less degree, according to the closeness of the association and the extent to which they have the same or similar requirements, since each species exerts some influence upon all others with which it competes for light, air, soil and water. By such competition species are eliminated from plant societies more frequently than by any other factor.

Of even more importance in affecting the composition of plant associations, and the places which these shall occupy is the influence which plants exert upon their habitat, by affecting drainage conditions as pointed out above and by concentrating mineral and other beneficial and noxious substances near the surface of the soil by their growth and decay. Each bog plant society so modifies its habitat, that sooner or later it can no longer hold it in competition with more aggressive associations and gives way before them. This modification proceeds until the rate of change produced by the plants about balances the change caused by ordinary weathering and decay, but it is of the greatest importance in considering the relations of the type of plant societies which have been under consideration.

The conclusions reached in this discussion, if valid for the region covered by the investigation, should have a much broader application than is given them, and as is shown in another paper, they have proven valid, when applied to the conditions existing in the more northern region of the Northern Peninsula of Michigan and should do so for any other.



ht 1907, by A. J. Farmer

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So many comprehensive lists of works relating to peat, its formation, and especially its utilization have been compiled and issued within a short time, that it has not been thought necessary to add another, which would perforce, largely duplicate those already in existence, and only such titles are here listed as have been especially cited or consulted in the preparation of this paper, or which seemed definitely to pertain to the problems involved in it, or to the distribution of peat bogs and peat-forming plants in the region in which most of the work of the investigation has been carried on.

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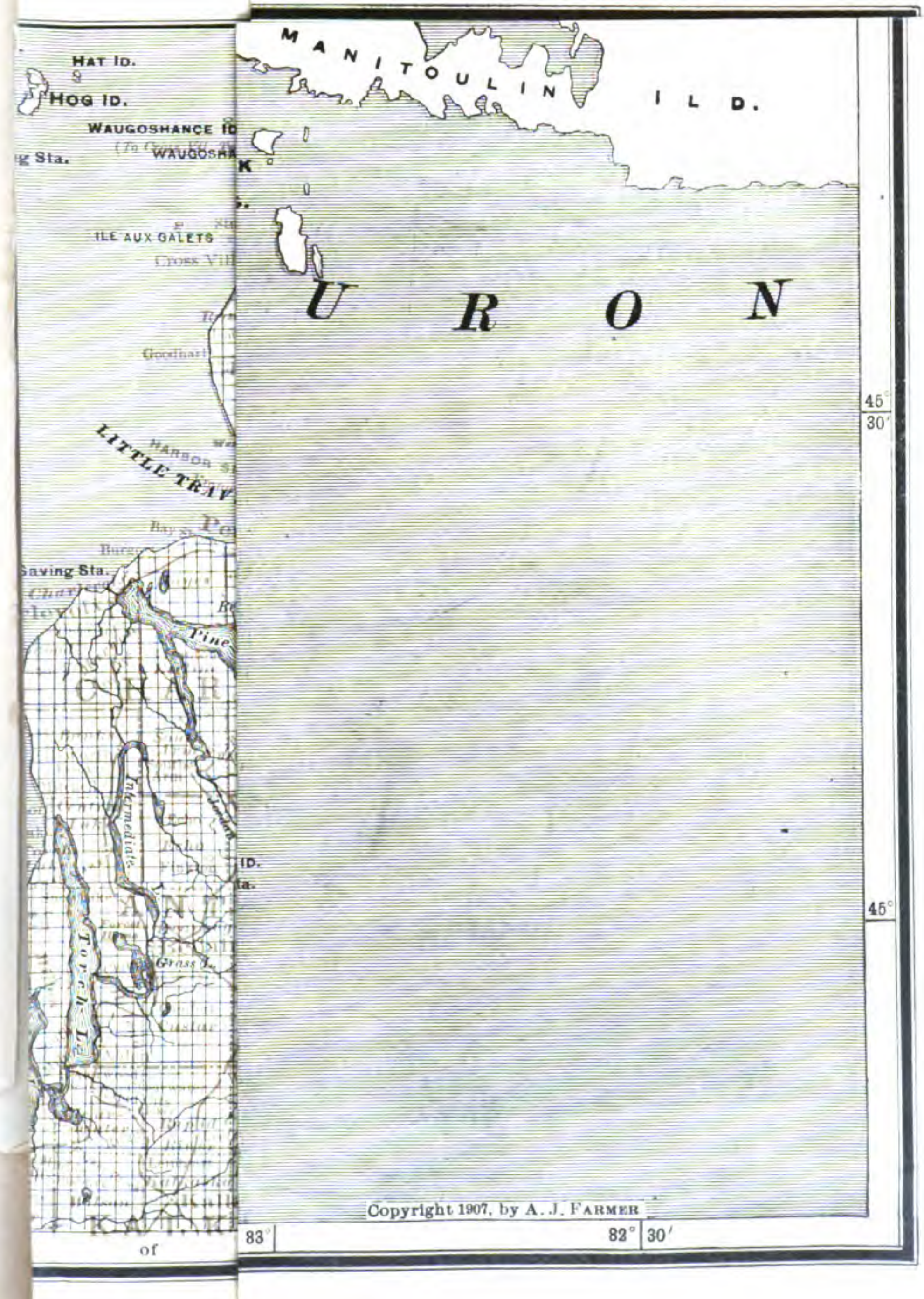

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PART II.

THE

FORMATION, CHARACTER AND DISTRIBUTION OF PEAT BOGS

IN THE

NORTHERN PENINSULA OF MICHIGAN

BY

CHARLES A. DAVIS

Introduction and Acknowledgments.

On July 1st, 1905, the writer, acting under instructions received from A. C. Lane, State Geologist, a few weeks before, left Ann Arbor for Bay City, where a brief study was made of the conditions existing along the shore of Saginaw Bay a few miles north of the city, upon some interesting stages of the formation of a minor lake from a portion of the Bay, which is being cut off from the main body by bars and a long spit, built by wave and current action aided by the growth of various plants. The lake thus formed is also being filled by the combined action of silt and the growth of water and shore plants.

This work was greatly facilitated by Mr. G. M. Bradford of Bay City, who pointed out favorable localities for study, and in other ways extended most hearty cooperation.

On July 4th Bay City was left for Frankfort, en route for Menominee, at which place the party of Professor I. C. Russell was to be joined. Having to wait a half day for the ferry boat across to Menominee, the time was spent in the study of the relation of the vegetation to the water level along the shore of Lake Michigan and upon the high bluffs bordering the lake on the south side of the mouth of the river.

A series of very interesting facts regarding the air currents blowing from the lake, upon and around the bluffs was noted as the day was unusually favorable for making such observations. The probable bearing of these facts upon the distribution of the plants upon the bluffs is of considerable ecological interest, but the discussion of them is not germane to the subject matter in hand, so they will not be recorded here, but will form the basis of a later paper.

Menominee was reached late in the evening of July 5th and on the following day I joined Professor Russell in camp on the banks of the Menominee river, a few miles north of the city. The objects of a visit to this section of the state were several, so defined in the letters of Mr. Lane and in conversations which we had upon the subject, and these finally settled themselves in the following order.

(1.) A continuation of the study of the development and characteristics of peat bogs, begun in the Southern Peninsula two years before, to determine, if possible, whether the principles worked out in that portion of the state were applicable throughout.

(2.) An ecological study of bogs and marshes to determine if the plants concerned in the formation of the peat were the same as those of the Southern Peninsula and also whether they followed the same succession in appearing upon the surface of the bogs, and in the swamps.

(3.) To find out the depth, degree of decomposition and the extent of the peat deposits visited, with a view to ultimate commercial utilization.

(4.) To study the distribution of the plants and plant societies which were found, to find out the zonal affinities of the flora, and in this way to gather data upon which to base a judgment as to the character and adaptability of the soil and climate to various branches of agriculture.

(5.) To examine uncut and cut-over timber land with a view to their future economic development, either for agriculture or forestry.

(6.) To note the occurrence, range and distribution of as many species of plants as it was possible to do in connection with other work.

From the outset, according to instructions, it was understood that the work which had been assigned to me was to be subordinate to that of Prof. Russell, so long as I was in his party, and that it was not in any way to hamper him nor to interfere with the general plan of his work. As the result of this understanding, the district covered by the investigation was limited, while I was with him, to that assigned to Prof. Russell.

This district, however, proved to be of great interest and gave a large number of excellent examples of various types of peat swamps, which more extended studies over wider areas, proved to be fairly representative in character, and in later studies no types were found which did not occur in this district. Aside from this it proved to be quite varied in topography and soils, so that it was possible to secure a large amount of material for the study of the general distribution of plant societies in a part of the state which has been but rarely visited by botanists, and about which little was known concerning the plant life.

The area studied while with Prof. Russell lies in the southwestern corner of the Northern Peninsula, and includes a greater part of Menominee county, and those parts of Dickinson and Iron counties which lie south of the north line of Township 42 N., and east of Range 35 W., a district which includes practically all of the settled portions of these three counties, and lies nearly all within the valley of the Menominee river, since that part of Menominee county which is drained by the Cedar river was not usually visited, although it was at times touched here and there.[1]

The excellent photographs, except those accredited to others, from which the plates accompanying this paper have been prepared, were made by Prof. I. C. Russell, whose rare skill and trained judgment in selecting subjects and times for photographing, were always at the service of the writer, during a greater part of the field work on which this paper was based. The films were furnished and developed and prints were furnished by the U. S. Geological Survey, co-operating with the Michigan survey.

The writer would also acknowledge in this place, his appreciation of the unfailing patience and courtesy of Prof. Russell, who furthered in every way in his power, the special investigation of the writer, and by his kindly interest and friendly criticism, did much to increase the value of the present paper, and it is a matter of profound regret that he did not live to see the completed work.

Acknowledgment is also made in this place of the obligations of the writer to Mr. Alfred C. Lane, State Geologist, for his constant and most helpful co-operation in securing material, pointing out favorable places for study, and literature relating to the region, as well as for the time spent with the writer in the field, and in other ways, while assisting in the collection of data for this work.

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[1] For a detailed account of this district the reader is referred to the paper by Prof. Russell in another section of this volume.

To Mr. Frank Leverett, of the U. S. Geological Survey, the writer would express his thanks for his kindness and assistance, during the few days spent with him, in the region between Newberry and Grand Marias.

The studies made in the Huron Mountains in 1906 were made possible by the kindness of Mr. Cyrus Bentley of Chicago, who extended to the writer the hospitality of his camp in the heart of this interesting region, and gave every facility possible for its examination. Thanks are due to him also for the illustrations from the region, Plates XXVIII A & B.

Itinerary and Area Studied.

The investigation of this region was carried on in somewhat the following manner. The party, consisting of Prof. Russell, a camp keeper and cook, and myself, would fix upon a camping place from which the country around would be worked over in such a manner as the requirements of the geological work demanded, and, while this was being done, my notes and studies were made. The roads traversed were so frequently cut through standing forests, and undrained swamps, that it was not necessary to go far from them to get satisfactory opportunities to study the flora, and as a general thing much of the material gathered was picked up while the writer was accompanying Prof. Russell in his work, and it was rather infrequently the case that it was necessary to delay him or to leave him to take time for independent work, although this was at times done.

The time for which the camp was located in one place was varied from a single night to nearly a week, this depending upon the character of the country and the quality and number of the roads which could be profitably reached from the point where the camp was placed. In all, 17 camps were made, in the 8 weeks during which I was with the party, and some of these camping places furnished most important data bearing upon the problems under investigation, and the others furnished most interesting problems in themselves, some of which still remain unsolved.

The study of the swamps and the plant societies of the uplands of this area was of such interest that it was deemed best to continue it to the limit of Prof. Russell's journey northward, especially as it was known that in the vicinity of Crystal Falls there were numerous small lakes, about which it seemed probable that a number of phases of swamp development would be found, which had not been seen so far to the north by the writer. This expectation was fully realized, and it was not until Aug. 26 that I finally left Prof. Russell in the last camp he made, at Iron River, and acting under advices recently received from Mr. Lane, I went to Bessemer by rail to make comparative studies of an extensive tract of "typical peat bog" which lies some 8 miles to the north of that city.

Leaving Bessemer on the 30th of August, I joined Mr. Lane at Houghton on the 31st and made further comparative studies of swamps and bogs in that region, both to the south of that city, in the vicinity of the Winona mine, and to the north, in various places.

On the 5th of September, in accordance with a modification of the original tentative plan which was made early in the season, Marquette was visited and 3 days were spent in studying the bogs and marshes along the shores of Lake Superior near that city, especially those formed behind dune lines, a phase of peat formation which I had not previously been able to carefully investigate. In each of these three regions, some attention was given to the plant societies inhabiting other types of locality than the bogs, and some valuable matter pertaining to the distribution of some of the more critical species of plants was obtained.

The final stage of the investigation was begun at Newberry, Luce county, on the 9th of September, when I joined Mr. Frank Leverett of the U. S. Geological Survey, and spent nearly a week with him in the region lying to the north and west of Newberry, and extending to the shore of Lake Superior. This region was traversed partly by driving, but chiefly by walking, and not only were a number of swamps and bogs visited, but a fine opportunity was afforded to examine a number of types of forest, and to observe the plants in the duny littoral region of Lake Superior, between the mouth of Big Two Hearted river and Grand Marais. A very short time was spent upon the shore of Grand Sable Lake and on the "Sable Banks" as the region to the west of Grand Marais is called, and a few notes upon the vegetation in that vicinity were made.

The return trip to Newberry was made in a single day and little time was available for detailed work, but the region was one of the most primitive visited, and a careful examination of it would probably lead to some very interesting results, as the hardwood forests are extensive and dense and at present very little disturbed.

A brief examination of the extensive peaty deposits in the vicinity of Newberry, yielded very little that was new, but the time available for the purpose was very short and it may be possible that a careful survey would show more that is of interest.

My return to Ann Arbor was made by the way of Trout Lake Junction and Manistique. At the former place opportunity was afforded by poor railroad connections to examine a series of swamps situated a short distance from the Junction, which had been formed between the sand ridge of the old shore line of one of the high level glacial lakes, Lake Algonquin. These swamps have been more or less frequently visited by fires and show a variety of stages of development of the surface flora.

A day was spent at Manistique in making an examination of the plant societies present upon the shores of Lake Michigan, west of Manistique and in studying the development of peat bogs between the sand dune ridges which were nearest the shore of the lake, as well as the stages by which the surface of these ridges became covered by a fixed plant population.

From Manistique, Lake Michigan was crossed to Frankfort, and again a part of a day was spent in the study of the vegetation upon the bluffs, for the sake of comparing the dominant types of herbs during the fall season with those which had been noted at previous visits to the same locality. My return to Ann Arbor was made the same day—September the 18th.

Methods of Work on Peat.

1. The plan of work adopted for the study of the peat deposits of this region was essentially that which had been used with good results in the work done in the Southern Peninsula, namely to visit as many of such deposits as possible, and examine them as thoroughly as the time at my disposal would permit: (1.) Making soundings to determine the depth and character of the peat: (2.) Noting the plants growing upon the surface of the deposit: (3.) Studying the relation of these plants to the water level, to the peat and to each other: (4.) Making notes upon the surrounding flora whenever this was possible. The time at my disposal was so limited and the difficulties of traveling through the swamps were so great that it was entirely impossible to make estimates as to the area of any of the deposits covered, nor did this seem desirable in most cases.

In order to compare the genetic development of these deposits with those of the southern part of the state, and to determine the plants most important in the formation of peat it was soon found that here, as there, that it was necessary to make studies along the margins of the ponds and lakes, or in the open swamps, since the tree covered areas represented practically the end of the cycle, that is, they were the final or climax stages in the history of the formation of the peat, and little bearing upon the problem of its development could be learned from them.

Around the open lakes, however, often a series of stages was found giving quite completely the history of the bog from the time it appeared above the surface of the water, just as has already been stated in the paper which relates to the Southern Peninsula, and it was in these open swamps that a very considerable part of my time was spent, making descriptions of the conditions existing in them.

2. On other problems. The extent of the territory visited and the brief time which could be given to any locality made the exact and detailed study and mapping the areas of any size, even in a very general way, impracticable if not impossible. After a good deal of consideration it was decided to see as much of the district as possible, and to learn what the most important types of locality and their attendant plant associations were, and then by gathering full data in a good many places where these types occurred, work out the details of the chief plant associations.

In addition to these descriptions of average conditions, all species of plants, which were only seen a few times, or but once, were recorded and notes made on their place of occurrence, abundance and habitat, as a matter of record for determining the limits of distribution, and, a considerable number of species hitherto supposed to be confined to the Southern Peninsula were thus noted.

In all cases where there was doubt as to the identity of any species which was found, specimens were collected and pressed for further study, if final determination could not be made without this, and all new records of distribution were confirmed in the same way, but no general collecting was done, because of the amount of time required for properly caring for the specimens in so moist a climate, and the difficulty of transporting the necessary presses and drying papers from camp to camp.

Types of Locality Examined.

The types of locality chosen for comparative study were (1) Swampy areas of all kinds: (2) Clay till ridges, both moraines and drumlins: (3) Sand plains and ridges of a number of kinds, so far as origin goes, such as eskers, sandy moraines, etc.: (4) Outcrops of sedimentary, metamorphic and crystalline rocks: (5) Sand dunes, especially those along the shores of Lake Superior: (6) The waters of lakes and streams: (7) Cut-over lands, especially pine lands.

In making records in these types of locality, the soil, its condition, the amount of moisture and humus, the dominant vegetation, the slope and exposure to winds, the amount of disturbance to which the vegetation had been subjected, etc., were generally taken into account and a full list of all the plants found over a considerable area was made, with notes of abundance and such other items as might help in understanding the association of species as recorded.

General Distribution of the Plants of Northern Michigan.

Making the form of the land surface, or the topography, the basis of classification there were three fairly well characterized districts in the region visited.

The first of these lay relatively near the shores of Lake Michigan and extended from Menominee well north, nearly to the iron region. This was characterized by relatively large areas of flat or slightly rolling plain, with isolated, low, long and narrow, stony clay hills, or short ridges, known as drumlins, scattered over it, either singly or in groups. In the valleys between these there were frequently found irregular, often winding, gravel or sand ridges, called eskers, which were also of no great length, a few miles at the most, and associated with them were sand and gravel knolls and hills, called kames.

Near the shore of Lake Michigan the surface was more sandy and much smoother than it was inland and had several well marked terraces at different levels above the lake, and, in places, practically continuous ridges of sand roughly paralleled with the present lake shore, which mark the shore lines of former levels of the lake and its predecessors.

The origin and nature of these types of ridges are fully discussed by Russell[1] for this region, and need no consideration here.

The drumlins were covered originally by heavy forests of mixed broad leaved species, of which the Hard Maple, Beech, Basswood, White and Rock Elms and Ironwood were the most common, with usually a considerable percent of Hemlock and scattering individuals of Balsam and White Spruce and in the northern part of the district, more or less Yellow Birch, which ultimately replaces the Beech entirely in this association a little farther to the north.

Upon gravelly or sandy ridges, whether of the esker, the beach or the

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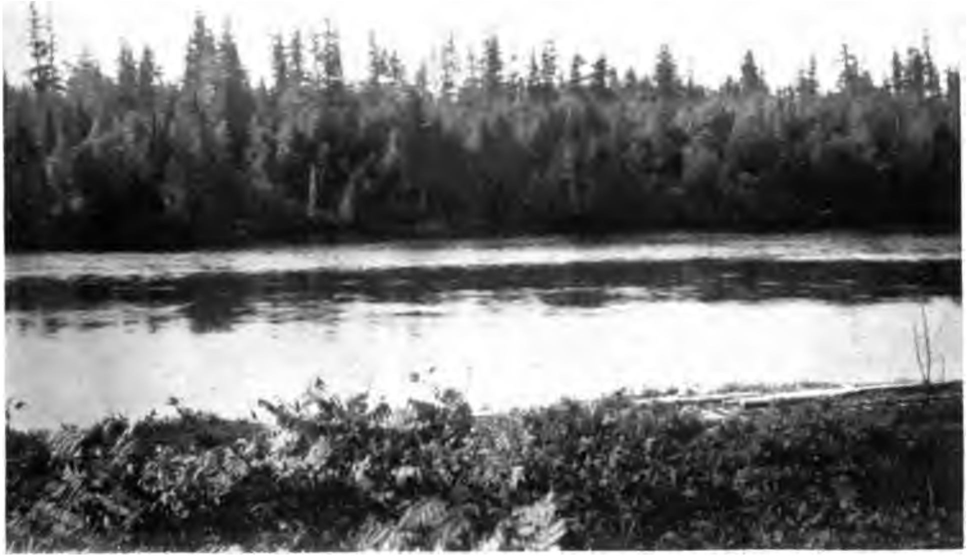
[1] Russell, I. C. A Geological Reconnaissance along the North Shore of Lakes Huron and Michigan. Annual Report, Michigan Geological Survey, 1904, pp. 65–95, Lansing, 1905. Also in this Vol., The Menominee Region.



Old White Pine forest with hardwood and lower growing conifers below, near Koss, on Menominee river. The forest is on the Wisconsin side of the river.

dune type, and upon sandy stream terraces and sand plains, the forest was formerly almost pure Pine, usually White Pine, but upon the lighter sands, the Norway and Jack Pines often were mixed in considerable abundance, or even formed nearly pure stands of one or the other, or of an even mixture of both species. In some areas along the Menominee river, and in other localities as well, where there was an admixture of clay and sand, or where there was a thin layer of sand over a pebbly clay loam, there were "two storied" forests, the upper story of very tall old White Pines, and the lower one of mixed broad leaved species, with Hemlock, Balsam, White Cedar, and White Spruce, as in the case of the forests of the drumlins. In these mixtures the White Pines tower high above the other species and practically all their branches are above the top of the lower story.

An excellent example of this type is shown in Plate XVIII, an old White Pine forest, with hard wood and lower growing coniferous trees forming the lower story, near Koss, on Menominee river. The forest is on the Wisconsin side of the river.

In this case, and in others as well, there was good White Pine reproduction, showing that the type tends to perpetuate itself.

Examples of these types are rare now, since the Pines have been cut or fires have destroyed them and the areas formerly covered by them are now growing up to Aspen, the large-toothed Poplar, Scarlet Oak, White Birch, and Red or Pin Cherry and to Sweet Fern and Bracken Fern.

The bottoms of the valleys, especially where these were poorly drained, were swamps in which Cedar or Arbor Vitae, Tamarack and Black Spruce were the most abundant tree species, although in some there were Black Ash, White Elm and Yellow Birch, usually associated with the three species first mentioned, and, much more infrequently, without them.

The second type of district, lying to the north and northwest of the first, and merging into it, may be termed the rock ridge type, in which the general surface was rather level or slightly undulating, with the relief in the form of high ridges of rock, these extending as lines of hills for miles across the country, with the flatter areas between them.

In this district the hardwood or broad-leaved type of forest was again found covering the ridges, and often the rock surface was entirely covered by thin soil, upon which, if undisturbed, was supported a fine growth of large trees. In many places, however, the timber had been cut and consequent fires, washings by rains, and denudation by the winds, had entirely removed the soil, so that the rock was quite bare, except in crevices in which grew a few stunted specimens of the more hardy trees such as the Aspen and the White Birch.

The better drained of the flatter areas here, unless sandy, were covered by hardwood forests with a mixture of Hemlock, Balsam, White Spruce and Arbor Vitae, while the terraces of the streams, sand and gravel plains, and the eskers which occurred frequently in the valleys, were formerly covered by White Pine, unless the sand was very light, when the Norway Pine took its place, and more rarely the Jack Pine. As in the former case, the pine forests have been cut, and following the cutting, the ground has been burned over again and again until there is very little Pine now on it, the only trees being the Poplars and other species mentioned in describing cut-over lands above.

In this district, the valleys were often quite extensive and well marked and the bottoms were covered by swamps, in which the same trees mentioned under this type of habitat above, were the characteristic species, and form the usual growth.

The third type of country was found to the northward and northwestward of the other two and in it. besides the rock ridges mentioned under the second type, there were extensive ridges of bouldery clay loam or "till" similar to that which makes up the drumlins, and of the same origin, namely, deposited by the melting ice of the last glacial ice sheet, which at one time covered the whole country. The ridges under discussion were formed at the melting margin of the ice from materials which had been carried in it or were pushed up by it, and are called moraines. They were often more than a mile broad, of varying height above the rest of the country, and ran for miles across it in practically unbroken lines, while between them and the sand and gravel plains which accompany them were numerous depressions in which occur lakes of various sizes. The broad valleys between these ridges were sometimes sandy upon the sides and bottoms, but more often they were so flat as to be poorly drained and covered by swamp forests of large extent.

Extensive deposits of sand and gravel, both in the form of plains and of terraces and ridges along the sides or bottoms of the valleys were sometimes the accompaniments of the moraines.

The forests upon this type of ridge were chiefly of Hard Maple, Elm, Basswood, Yellow Birch and Black Birch, with Hemlock, Balsam, White Spruce and Arbor Vitae generally present, the latter three species as undergrowth, and in some places forming a considerable part of the timber. The Beech was not seen in this part of the area studied, being replaced by the Yellow and Black Birches. The Hard Maple was often the most important species along the tops of the moraines, making up from 50 to 70 per cent of the forest and in such places there would be no coniferous trees at all, or only a few small specimens of White Spruce or Arbor Vitae. On the other hand on the lower slopes of the ridges and on the flat lands adjacent, if not too wet, the Hemlock and the Balsam and White Birch will be numerically in the ascendancy, and the Maples few in numbers.

Soil and Topography of the Region in Relation to the Plant Societies.

Sandy ridges, the better drained valleys with sand bottoms, and gravel and sand plains, were formerly densely stocked with pine forests, the poorest and lightest sands having chiefly Norway Pine and Jack Pine, while the better sands and the gravel supported White Pine, here as elsewhere, but they now, except in rare instances, are covered by Poplar, White Birch and other poor kinds of broad-leaved trees, little Pine of any species persisting at the present time, except where accidental isolation has preserved small numbers of individuals from destruction by the fires which followed lumbering.

The poorly drained valleys and till plains and all other places, where there was an abundant supply of water, were covered by a dense growth of Tamarack, Black Spruce, and Arbor Vitae, either growing together or quite as frequently with one or the other species predominating—the Black Spruce especially in the bogs around partially filled lakes and the Arbor Vitae mixed with the Balsam on the higher parts of swampy margins of streams and in springy places.

The Tamarack was most often found in extensive growths, forming dense, pure stands upon wet marshy tracts, either around lakes, in swampy valleys, or in any poorly drained place not already covered by other dense tree growth.

It is evident, therefore, that throughout the entire region, there was a well marked relationship between the type of soil, considered with regard to its water-holding power and drainage, and the plant association covering it. The main distinction which was noticed in this portion of the state as compared with other parts which have been visited, was that here comparatively slight disturbances of the drainage produced permanent swamp conditions, and this tendency increased, apparently, the farther north the investigation was carried until the valley of every rill was filled by a swamp.

On the other hand, except on rock hills, where sometimes 2 to 3 feet of humus had accumulated, there was usually only a slight development of humus upon the tops and sides of even the clay ridges, where the forest cover was most dense, although these gave evidence that they must have been covered by vegetation from almost immediately after the retreat of the glacial ice, in that there were practically no indications of rain erosion, even upon very steep slopes.

Types of Forest.

In order to more clearly present the general relationship between the swamps and the surrounding vegetation, an attempt has been made to classify the whole flora into a series of easily recognizable and fairly constant and characteristic types.

Summing up, there seems to occur in all these types of habitats, five fairly distinct and well-marked forest types, which may be characterized as follows, in the order of the extent of areas covered:

(1.) *The Broad-leaved, Hardwood or Deciduous Forest.*—This was the type which covered the better class of well-drained uplands, including the rock hills in undisturbed regions, and was the important forest of much of the region visited. The dominant species of trees in this type were Hard Maple, Elm, Basswood, Beech, in the south, and Yellow and Black Birch in the north, with more or less mixture of conifers, especially Hemlock, which sometimes is present to a considerable extent, and Balsam, White Spruce and Arbor Vitae, usually, when present, evidently recent comers, growing up in the shade of the hardwoods. In some cases White Pine was a constituent of this type, occurring as scattered individuals or small groves in the more sandy places or near the borders of swamps. In other areas all conifers were absent for long distances from the higher lands where the hardwoods reached their best development.

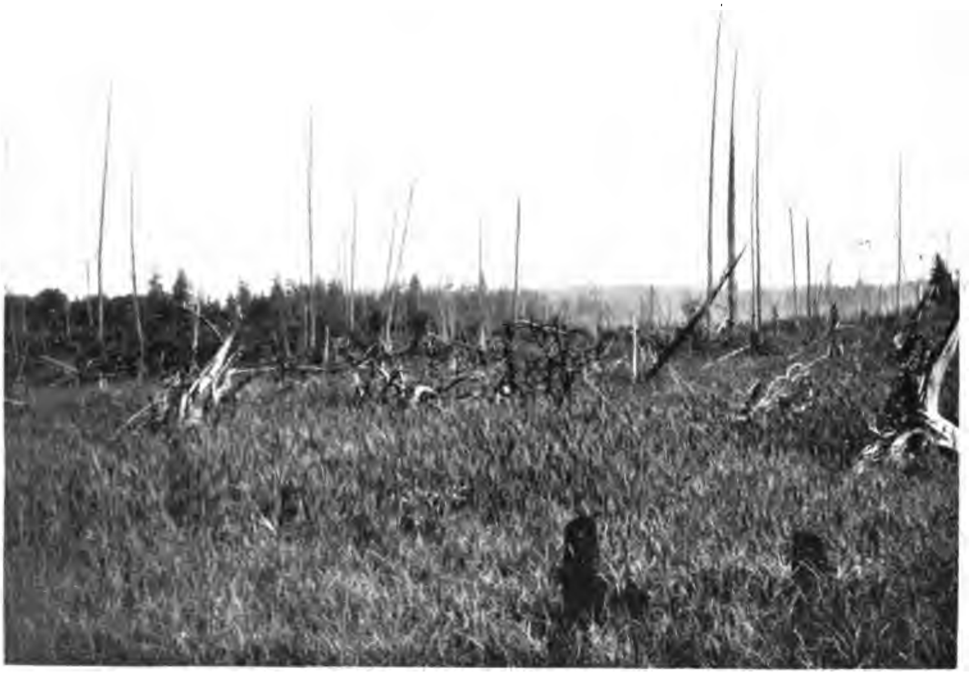
(2.) *The Coniferous Swamp Forest.*—This covered all of the undrained or poorly drained flat lands, including the peat bogs. The more mature swamps had what has been called by the writer the Cedar-

Tamarack-Spruce Association, in which frequently the Arbor Vitae or Cedar, was the dominant species, with a larger or smaller mixture of Black Spruce and Tamarack. The Tamarack, however, was very often abundant or dominant, and the Black Spruce sometimes covered considerable tracts with very few individuals of the other species present. In numerous cases the Cedar was wanting from the association where the other two species were present in about equal numbers. In this type also occurred at times the White Pine, the Jack Pine, and sometimes a few scattering Norway Pines and upon the borders, Balsam and White Spruce; Black Ash, White Elm, Balsam, Poplar, Red Maple and a few other species of swamp trees also were present in numbers sometimes sufficient to give a mixed character to the type, but this was rather unusual.

(3.) *The Hemlock-White Spruce-Balsam Type.*—This is also a coniferous type, and was found on well-drained flat lands and upon gentle slopes on the sides of the valleys. It had as fairly constant constituents, the White Birch, Yellow Birch and, in many cases, Arbor Vitae; in fact, most of the species of other types of associations occurred in it at times, but the species given were so frequently found together that an easily recognizable type can be maintained, which, in general, grows in situations intermediate in characters between the Hardwood and the Swamp sites. Hemlock was the dominant species of the association and more frequently formed dense pure stands than either of the other species, which, rather rarely, were found in groves.

(4.) *The White Pine Type.*—Much more variable than any of the others was the type of forest in which the White Pine was the dominant species, from the great variety of conditions in which that noble tree will grow and thrive. Unfortunately the greater part of the White Pine in the regions traversed had been cut, but a few remnants remained, and the large areas of stump lands showed that at one time the type had been an important one. In this type are included all the mixtures in which the White Pine was the leading species in point of numbers, so that the range is from the two-storied White Pine and hardwood forest in which the old pines rise above the lower growing species, through the pure stand of White Pine, to the mixture of the three species of pines in which the White Pine was the important species numerically. This would include all soil types, from gravelly loam with considerable clay in it, to poor but rather moist sands. This type apparently did not cover great connected areas as did the Hardwood type, but was confined to relatively small and disconnected areas of gravelly deposits of various geological history, and to partially covered rock outcrops.

(5.) *The Norway and Jack Pine Forest.*—Of more restricted distribution still was this interesting type, which seems to have been confined to tracts of dry, deep, thoroughly drained sand, whether in the form of ridges or plains, and the borders of tracts of this type of forest were often very sharply defined. Glacial sand or gravel plains, deltas, and sand dunes were the common habitats of the type, which is made up of rather open stands of the two species of pines which characterize it, mixed with some broad-leaved species, such as Poplars, Scarlet Oak and Red Maple, which grow with the pines in the most barren places. The type also occurs on sand ridges, a foot or so above the water level in many swamp areas, and sometimes invades the swamps themselves. The



Mature Conifer bog, near Mansfield, rejuvenated to wet-sedge stage by severe fire, and now occupied by dense growth of Cat-tail. The surface was lowered at least two feet by the burning as shown by the upturned roots of the trees, from around which the peat was completely burned away. Uninjured swamp in the background.

accumulation of humus under this type amounts to very little, in many cases to nothing apparently, although no evidences of fire could be discerned even by careful inspection. The Jack Pine, in young dense stands, was sometimes found growing in dryer parts of peat deposits.

The Drumlin Region Peat Deposits; Valley Bogs, Their Characteristics: Important Plant Associations of this Type.

The examination of deposits of peat began in the vicinity of Menominee, where, a short distance to the north of the city, there are numerous and practically unmodified Cedar, Spruce and Tamarack swamps which have an abundance of peat in them, and which afford interesting examples of the partial filling of shallow valleys by the growth and decay of vegetation.

The valleys in this locality are, in part, formed behind the ridges which mark the beach lines of higher levels of Lake Michigan and its predecessors, and in part lie in the grooves between the drumlins and the drumlin-like hills which are found in considerable numbers for many miles to the north of the mouth of the Menominee river.

These valleys are relatively broad and very shallow, with generally sandy bottoms, which may have a thin covering of fine clay, or, in a number of cases, what appears to be a grayish marl. Sometimes small streams run through these valleys, but frequently they have no running water in them, draining slowly towards the streams, the passage of the water being much retarded by the peat accumulations. The thin layer of clay or marl, which is found at the bottom of these beds of peat, seems to indicate that, in the beginning the valleys were occupied by very slow moving streams or shallow ponds, because such conditions favor the deposition of the fine mud or the growth of the aquatic plants which deposit the calcareous material which forms the marl. In no place visited in this vicinity were there any indications of the early stages of the process of filling these valleys and the order in which the plants forming the peat have invaded them, except that mentioned above, i. e., the marl. If, in the earliest stages, the valleys contained shallow ponds, it is highly probable that the first stages of the filling were done by aquatic plants, and that these were succeeded by the marsh plants.

The depth of the peat in these deposits is not great, many of them being but 2 or 3 feet deep, and they rarely exceed 8 feet, but the quality of the peat in them was better than that in the deeper deposits which were examined later, and after the surface layers, containing stumps, fallen logs and the roots of growing trees were passed through, much of it seemed sufficiently compact and well decomposed for economic uses. The color varied from light to dark brown, or, rather rarely, to black, and the amount of water was not excessive. There were in the aggregate, large areas of this kind of peat bog within a few miles of Menominee.

The plants growing upon the surface of these deposits where they had not been cut or burned over, were usually a mixture of the following tree species: Tamarack, Black Spruce and White Cedar or Arbor Vitae. These were dominant or leading species, but with them were frequently small numbers of Balsam Fir, Black Ash, Balsam Poplar, Yellow Birch, White Birch, Red or Soft Maple and Mountain Maple. The accompanying species were only present in a part of the swamps, and in these were usually found around the borders, or in partial clearings.

In the best examples of this plant association seen in the region under discussion, that is, in which the trees were fully mature or past maturity, the marketable Cedar had been cut out, leaving the Tamarack and Spruce in numerical excess, and in rather open growth, while beneath these was usually a rather dense growth of low shrubs, chiefly those belonging to the Heath family.

Of these, the Cassandra was usually the dominant species and with this were present, in greater or less numbers, other species of the same family, of which Andromeda, the Pale Laurel, the Labrador Tea, and one of the low bush Blueberries, were the most frequent and noticeable. The Andromeda is especially conspicuous from its pale, bluish-green, narrow leaves, which are nearly white when young, and the Labrador Tea from the yellowish green color of the upper surface of its leaves and their dense woolly covering below. With these Heaths it was usual to find the Dwarf Birch, and not infrequently the Swamp Honeysuckle, which, in places, became the most abundant shrub. In spots where conditions were favorable, and especially where fire had destroyed the older vegetation, the Common or Speckled Alder was frequently the most important species present, and even in apparently undisturbed places in the peat swamps, it was sometimes seen in greater or less abundance, although it was not so common in this type of habitat, as along streams.

The herbaceous vegetation of these tree and shrub covered swamps in this particular area was made up largely of sedges belonging to the genera *Carex* and *Eriophorum*. Other types of herbs were present in the association, but were not large or constant constituents of it, and *Sphagnum*, the peat moss, was more often absent than present in the places visited, in fact, is noted as rather rarely occurring.

In places where fire has swept lightly over these swamps, simply destroying the surface vegetation, there frequently springs up a dense growth of young Tamaracks, which seem to be more hardy and more able to endure the conditions presented by this type of habitat than either of the other species of conifers, which, in other conditions, associate with them.

Here, as in the other regions visited, many instances of the effects of severe fires in changing the entire character of the vegetation growing upon the surface of peat deposits were noted. If the fire burned the peat so severely that the surface was lowered to such an extent that it was below, or very near, the subsequent ground water level, this area became covered by a growth of Cat-tail more frequently than by any other species, and as evidence that it was fire which had brought about the change, among the flags could usually be seen the dead and charred stumps of the trees which had formerly occupied the ground. Not uncommonly the edge of the fire scar would be abrupt, and this border would be marked by a fringe of tall old trees, and the accompanying shrubs which characterize the mature swamps.

One of the best of many examples of this form of accidental lowering of the surface of a peat deposit, was seen on the road from the Mansfield Mine to Crystal Falls, in an extensive valley swamp, a part of which is shown in Plate XIX.

In a relatively small area of sandy plain which lies in the big bend of the Menominee river, about 20 miles north of Menominee, there were numbers of shallow deposits of peat, from 1 to 3 feet deep, upon which were growing old Tamarack and Spruce trees in stands as dense as these trees usually form, a fact which is indicative of the unreliability of the indications of the surface vegetation as to the depth of the peat upon which it may be growing. In this area, in Tp. 35 N., R. 28 W., the following species of plants were noted growing under a forest of large and tall old Tamarack in a shallow depression in the plain:

Young White Cedar, Young Black Spruce, Young White Pine, Young Balsam Fir, Common Alder, Dwarf Alder or Buckthorn, Red-osier Dogwood, Swamp Honeysuckle, Dwarf Raspberry, Bunch Berry, Twin-flower, Swamp White Violet, Bristle-stalked Sedge, Little Prickly Sedge, Porcupine Sedge and Marsh Shield-fern.

In this locality there was very little Sphagnum. Another swamp of the same type, so far as tree growth is concerned, had the following species, not noted in the list given above, so abundant that they constituted practically the whole of the ground cover:

Cassandra (very abundant), Labrador Tea (growing on the elevations formed by the roots of the trees), Dwarf Birch, Hoary Willow (scattered among the other shrubs), Choke-berry (on the higher stools formed by the tree roots, etc.), River-bank Sedge (in the wettest places between clumps of shrubs), and Tussock Sedge.

Most of the herbs mentioned in the lists above, were present as minor constituents of the association, growing on the more exposed elevations above the water.

Partially Filled Lakes of This Area: Ways in Which They are Filled.

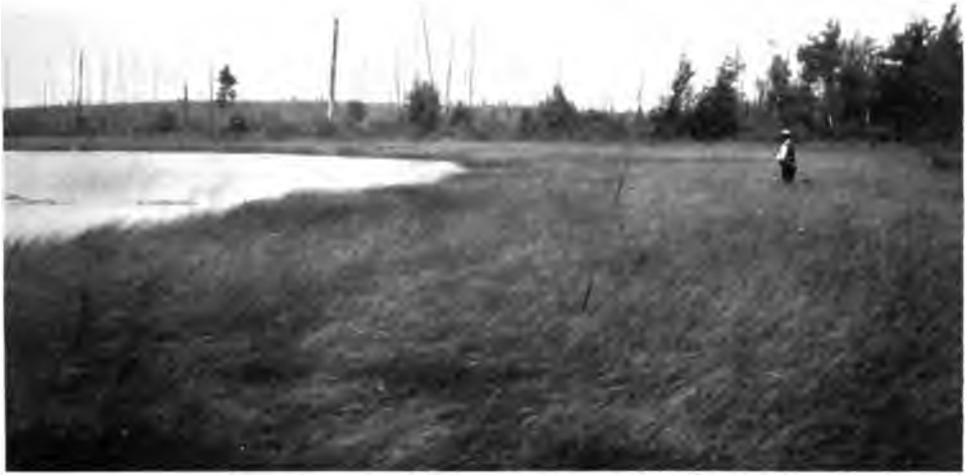
A few lakes were found in this area and of these, Hayward Lake, occupying parts of sections 2, 3, 10 and 11, T. 34 N., R. 26 W., situated about five miles east of Ingalls station on the Chicago and Northwestern R. R., was the largest and first visited. This lake occupies a shallow depression near the border of the glaciated region and is surrounded by low drumlin-like elevations. There are several small islands in the lake and it seemed quite shallow from the north shore, which was the one visited. A large part of the shore was swampy, only two or three limited areas being high enough to support a dry ground flora to the edge of the water. The major portion of this swampy shore was covered to the water's edge by shrubs, of which the Dwarf Birch and Swamp Honeysuckle, several species of Willow, of which the Hoary Willow was the most conspicuous, and a constant admixture of Sweet Gale, which became nearly pure in a zone of varying width at the lakeward margin, where it was growing vigorously in water from a foot to 16 inches deep. The zone of shrubs had a width of from 40 or 50 feet, up to several hundred feet, in the part of the shore visited and was practically afloat with water several inches deep, only the elevations about the bases of the bushes being above water at that time, early in July. The margin was quite unstable in places, scarcely firm enough to bear the weight of a man, and settling perceptibly as it was stepped on. In the water beyond this quaking margin, were scattered plants of the Yellow Pond Lily, the White Pond Lily, and the Pickerel Weed, together with patches of Lake Bulrush, in somewhat deeper water. In some places the latter plant with the Cat-tail, formed a more or less extensive border outside the shrubs; several of the islands mentioned above were covered by the same plants and upon one of them a small tract of Tall Reed Grass was established, while still others bore shrubs and trees. The peat, in the places where the depth was tested along the margin of the lake, was from 8 to 9 feet deep, and was soft and contained much water. Below this were 6 inches of fine reddish clay, then hard bottom.

In a small indentation in the shrubby margin on this shore, the often-mentioned Slender Sedge and the Cat-tail had built a floating mat a couple of rods or more in width, upon which the Sweet Gale and some few small patches of Cassandra had established themselves, together with the Marsh Shield-fern, Reed Grass, the Swamp Persicaria, the Marsh Cinquefoil, the Myrtle-leaved Willow, and three species of sedge, the Water Sedge, the Bristly Sedge and Lesser-Panicled Sedge; the Water Persicaria and the Marsh Cinquefoil were more abundant back near the shoreward margin of the sedge mat, and of the shrubs, the Sweet Gale seemed to be making the most vigorous growth. There was 6 feet of soft peat below this mat and 6 inches of sandy marl before hard bottom was struck.

Shoreward of the shrub zone, extending around nearly the entire lake, was a zone, of varying width, of pure Tamarack, under the shade of which were relatively few other plants, which were not listed. The water here was not so deep as in the shrub zone, in fact did not stand above the surface, although the ground was saturated with water an inch or two below the general surface, the roots of the trees alone furnishing a firm footing. Farther shoreward, where the ground became firmer and dryer, the Arbor Vitae and Black Spruce were dominant trees; in wetter places, the Black Ash and White Elm occupied considerable areas. Under these two species, the water was sometimes knee-deep in the depressions between the trees. In a well-marked zone, between the Cedar-Spruce zone and the high ground vegetation, at the foot of the slope, was a mixture of White and Yellow Birch and Balsam Fir, the first named species attaining a diameter of nearly two feet and being the dominant tree species. The high ground forest, covering a low ridge of clayey till lying to the north of the lake, was chiefly a mixture of Beech, Hard Maple, Basswood and White Elm, the trees all of large size, and forming a dense shade, under which but few species of shade plants were growing.

Later it was reported that there were extensive cranberry marshes near the lake, but no indication of these appeared in the area examined, as the shrub and Tamarack zones were very dense as far as could be seen, and as noted above, extended practically all around the margin.

The indications were in favor of the hypothesis, that at the time it was visited, the water of this lake was at least a foot higher than its normal level, as it seems hardly probable that some of the species of shrubs then growing in the water, would have been able to establish themselves where the water was so deep as in the places where they were found, and it is likely that the heavy rains, known to have prevailed a short time before, had recently raised the water level. Enquiries in the neighborhood regarding this point were fruitless, as the people living in



The sedge marsh on margin of a sand plain lake, shows besides the marsh: (1) Scattered Pond Lily leaves on the surface of the water; (2) Lake Bulrush in small quantity in the shallow water; (3) Standing stubs of burned White Pines; (4) Scattering young trees of the same species (on the left); (5) Young Pines and Poplars (on the right.)

this vicinity, said they rarely went to the lake, and knew nothing of the conditions existing at that time.

Apparently, filling in this basin is proceeding very slowly, and the greater part of it is being done by water plants, which are rather sparsely distributed along its shores in the shallow water, the absence of any extensive areas of sedge and the replacement of these by shrubby growth, pointing to relatively slow encroachment upon the open water by the plants, since the shrubs noted here, do not spread rapidly in the ways in which do the sedges.

The second lake or pond examined was a small one, of about 40 acres in area, in Sec. 3, T. 35 N., R. 28 W., in the sand plain mentioned above. This lake differed from Hayward lake in being surrounded by a pure sedge marsh on all sides except on the southwest, where there was a growth of Tamarack and shrubs shoreward of the sedge border next to the water. The species of sedge which occurs here was, so far as seen, entirely the Slender Sedge, and it occupied practically all of the margin of the lake basin from the sandy region above the water level to a distance of from one to two hundred feet out, where the water was more than two feet in depth.

At this distance from shore, the plants were growing in a soft oozy deposit of partly decomposed remains of water plants and growing algae, among which a species of Chara was easily recognizable by its whorled branches and peculiar odor. In this ooze the sedge was so lightly attached by its roots as to be practically floating; and it could be easily pulled away and turned over. The ooze was only a foot or two in depth below the edge of the growing sedge, and rested upon a sandy bottom in the places where it was tested. Growing in the water, beyond the edge of the sedge growth, where the depth was from two and one-half to five feet, was more or less of the Lake Bulrush, distributed in patches, usually of small extent. In the same zone and often associated with the Bulrush, were the White and Yellow Pond Lilies, and, more abundant than either here, the Water Shield, a small flowered member of the same family, together with the Floating Pondweed, and the Common Bladderwort, these, together, forming a rather sparse and broken zone, as far as the shore was examined.

Along the shoreward margin of the sedge zone, were logs which had fallen into the marsh from the shore, or had drifted thither during stages of high water and upon these were colonies of Marsh Shield-fern, and Cassandra. These plants were also found in small patches growing among the sedge plants near the dryer edge of the marsh, and there were also specimens of the Myrtle-leaved Willow,' other species of Willow and of the Marsh Cinquefoil. Above the level of the water there was a narrow zone of Blue-Joint Grass, which ran directly into the ordinary shrubby flora of the burned-over pine barren. This was not listed for this particular locality, but was made up principally of young growth of Poplars, both the common Aspen and the Large Toothed Aspen and the Wild Red or Pin Cherry, with a dense covering of Sweet Fern, the Bush Honeysuckle, the Common Brake, and a considerable number of low herbs and grasses. There was no time to visit the western shore of this lake, where a shrub and Tamarack zone were developed, but there seemed to be considerable extent of this type of swamp there, and it apparently extended along the outlet of the lake to a stream which flows a quarter of a mile west.

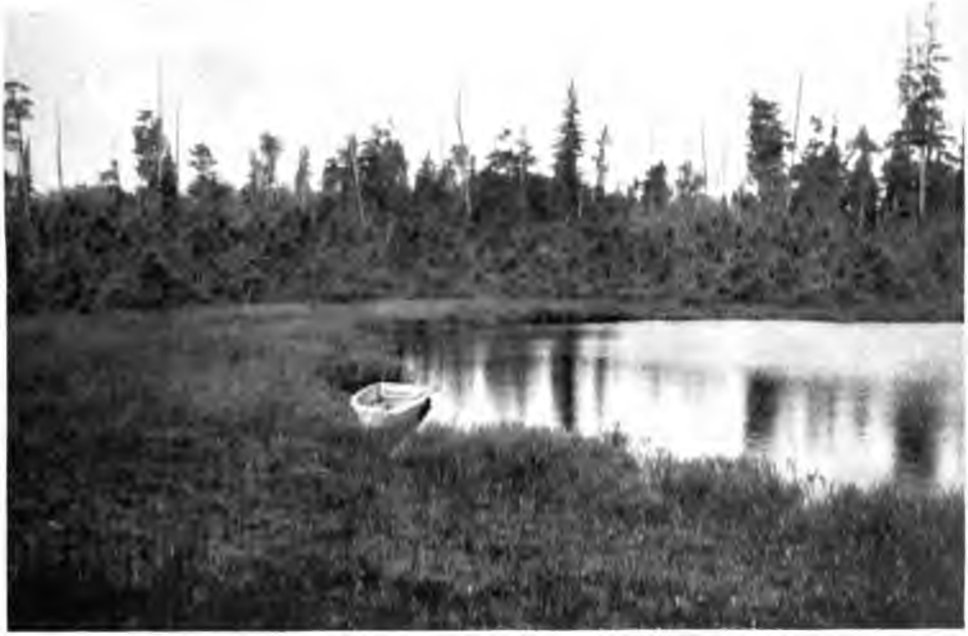
A portion of the margin of this lake is shown in Plate XX. This lake, as a whole, seems to represent a much earlier stage of the process of filling an extensive basin by vegetation, than does Hayward lake, and in every way, even to the species of the plants concerned, closely corresponds to the earlier stages of the process as worked out for the same type of basin in the Southern Peninsula, the only possible difference which could be noted being in the greater luxuriance of the growth of the water plants in the south as compared with that in this locality. Here the plants of the aquatic type were scattered and formed a very broken zone, but even this difference was probably no greater than would often be noticed in adjacent lakes in the south or even in neighboring parts of the same lake, in which, in one place, there will be a very luxuriant growth of this type of plants and in another a very sparse and poor one.

If a comparison of the plant associations of these two lakes is made, it becomes evident that the dominant association of Lake No. 2 corresponds very closely to the group of plants on the margin of the little inlet which was found at Hayward Lake and described above, but it is also clear that there is nothing at Lake No. 2 to represent the wide zones of bush and tree swamp which constitute the conspicuous features of the former in that part of the latter which has been described. The presence of some of the shrubby species which constitute the greater part of the association of the marginal zone of Hayward lake, upon logs and along the shoreward edge of the sedge marsh, is an indication that a distinct zone of shrubs will eventually be developed as the sedge marsh extends out over the lake, or at any time when the water level of the lake is lowered sufficiently to permit the shrubs to become established. It also seems probable that at Hayward Lake there has been a period of low water rather recently, during which the shrubs advanced to the margin of the sedge mat and so shaded it that the sedges were nearly exterminated, and have not yet had time to reestablish themselves since the water has risen, although conditions found farther north indicate that this is by no means certain.

Pond in Peat Bog at Nathan.

The third pond visited in this region is located at Nathan, a station on the Wisconsin and Michigan R. R. (Sec. 24, T. 37 N., R. 28 W.). This is a small pond of a few acres in area, a short distance west of the railway station, and surrounded by a peat bog of considerable extent and of a very interesting type. (Plate XXI.) The bog represents a stage quite near the end of the process of filling a lake basin similar to that last described, a shallow depression in a nearly flat country, which, however, in this case, was not sandy but covered by bouldery clay.

The surface of the bog seems to slope gently from the border to the margin to the lake, and actually does, to a slight degree, as was shown by the standing water in a ditch cut from the road which runs west from Nathan to the lake, but the effect is probably heightened by the fact that the Sphagnum, which covers the surface, is much more luxuriant



Lake margin at Nathan, Menominee County, shows: (1) The characteristic absence of aquatic vegetation in the northern peat bog lakes; (2) The narrow marginal zone of Cassandra in and over the water; (3) The Sedge-Sphagnum zone shoreward of this; (4) In the background, a dense growth of shrubs, stunted Black Spruce and taller Tamaracks.

in its growth some distance back from the edge of the water, than it is near it.

Vegetation of the aquatic type, is practically wanting in the lake, the only plants noted being a small amount of an aquatic moss, *Fontinalis* sp., and small patches, near the shore, of the thread-like leaves of Water Club-rush, while upon small areas of bare peat, just above the water surface, were, here and there, stunted plants of the Yellow Pond Lily and of a Pondweed, probably a form of the Floating Pondweed. The bottom of the pond was apparently entirely made up of dark-colored peat of rather coarse texture and very soft. Above the surface of the water the vegetation was abundant and at different parts of the shore was quite different in character and species. In general, on all sides of the lake, however, the marginal zone consisted of occasional stools of Tussock Sedge with more abundant plants of Creeping Sedge, and in much greater amount than either of these Cassandra and Andromeda sending out branches into the water, upon which as supports, the sedges and the Large Cranberry grew, and helped to form a mat upon which grew Sphagnum, and later, other species. Both species of sedge mentioned formed independent masses extending short distances from the shore. At a varying distance from the edge of the water, but never beyond the advancing shrubs, usually more than one foot and often several feet back, there was a dense growth of Sphagnum, forming a well marked zone from one to several yards in width. Growing with this and often confined to this zone exclusively, were:

Creeping Sedge, Mud Sedge, Sheathed Cotton-grass, White Beaked-rush, Large Cranberry, Small Cranberry, Buckbean,[1] Sundew,[2] Pitcher Plant,[3] Andromeda,[4] Cassandra,[4] and Pale Laurel.[4]

The surface of the Sphagnum in this zone varied but little from a foot above the surface of the water in the pond, and the moss itself was saturated with water. In some places the moss was less thickly crowded than in others and in some spots it was nearly absent, in which cases the surface was somewhat lower and wetter than where it was present, as would naturally be expected, and in such places the sedges were usually more thrifty than where the moss was more dense.

The shoreward margin of this zone was marked by a border of taller shrubs, of which Cassandra was the most conspicuous in point of numbers and size, and by large numbers of stunted Black Spruces from three to eight feet in height, together with a few small and slow growing individuals of Tamarack. The Spruces were also evidently making very slow growth, as shown by the short leaders and narrowness of the rings in stumps examined. They were also badly infested with the Small Mistletoe and many of the individuals showed the characteristic "Witches' brooms," which this parasite causes before the tree dies.

Associated with the Cassandra and Spruce was the Labrador Tea which did not occur at all in the Sphagnum zone near the water and grew here in the higher places, on the hummocks and stools about old stumps. Andromeda on the other hand was not abundant in this zone and was only seen occasionally in the part of the area visited. Aside from these plants the following occurred: Pale Laurel was abundant and of large size. The Pitcher Plant was not common and the plants seen were in poor condition as though not in a favorable situation, the leaves were small and few and the plants had not bloomed this season. In spots where openings in the shrub growth had developed, the Cranberries were able to cover the ground, but as a usual thing they were not present in this zone, but the little Creeping Snowberry was frequently seen running over the surface of the Sphagnum. The Three-seeded Sedge, the Sheathed Cotton-grass, and the Three-leaved Solomon's Seal were the only herbaceous plants seen besides those mentioned, the last named being very common. In the places which seemed the dryest, there were also occasional patches of the Canada Blueberry.

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[1] More common at the landward edge of this zone nearly buried in the Sphagnum.

[2] Also growing upon the bare mud near edge of the water.

[3] The leaves of this plant were practically buried in the Sphagnum, only the openings showing in many cases.

[4] The plants of these shrubs here were all short, many of them apparently young and recently established.

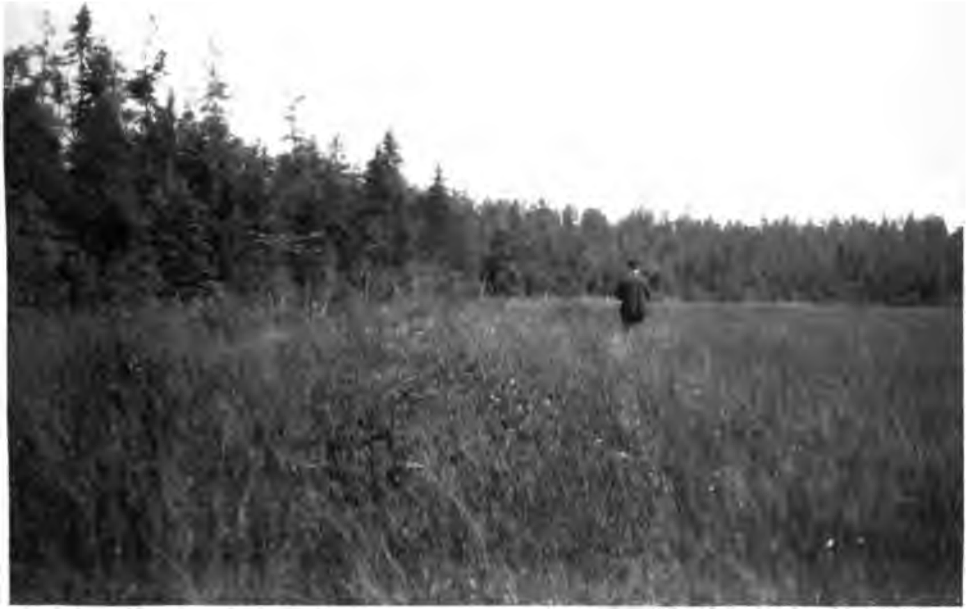
A rod or two back from the lakeward edge of this zone the Sphagnum was often very pale in color and quite dry at the top, as though dead, and it was only in the depressions and under the shade of the thin-foliaged, sickly specimens of Black Spruce that it seemed to be growing, and was green and fresh. Areas of several square feet in extent were frequent that were covered by the Reindeer Lichen which formed a dense mat upon the surface of the dead Sphagnum, apparently showing a condition of great dryness, since the Reindeer Lichen grows in this latitude only in the dryest situations.

In a few places the Sphagnum had built up mounds by the aid of the growing Cassandra bushes to a height of nearly 2 feet above the lowest part of the moss-covered surface, or slightly more than 3 feet above the water level, but the general surface of this part of the bog was from 18 inches to 2 feet above the level of the water, and it seemed apparent from the general condition of the Sphagnum plants that there would be very little growth above that level, unless the level of the water should rise, or the evaporation from the surface be checked in some way.

The peat here was more than 10 feet deep in every place where it was tested, and from the surface, through the first 6 feet, it was of rather coarse texture, compact and of a marked and unusually deep reddish color, quite different from the dark brown of ordinary peat. Below this it was finer grained, lighter in color and very soft and wet, but coherent enough to be brought to the surface in the sampler.

In the marginal zone, wherever the Sphagnum grew, the bog was firm and strong enough to permit walking over it with safety, but it was easily shaken, and lakeward of the Sphagnum would sink when stepped upon. In the zone of shrubs and spruce, the surface could not be shaken for more than a short distance even by jumping upon it with considerable force, so compact was the substratum.

This bog, more than any other which had been seen by the writer up to that time, would lead the casual observer to the conclusion that the lake was being filled by the advance of the Sphagnum over the surface. It was however, easy to see that such was not actually the case, for in no place around the entire margin of the open water was the Sphagnum growing in the water, in advance of other plants, and in the greater part of the margin it was a foot or more back from it, as has been noted above. Sometimes, however, the moss would be growing nearly at the edge of the zone of the advancing plants and the fact that it was not



Border of mature bog near Nathan, Menominee County, shows: (1) The abrupt transition from sedge-marsh with slight admixture of shrubs to coniferous swamp. The conifers at the left are Tamarack, Black Spruce and some Arbor Vitæ; on the right is less dense growth of stunted Black Spruce and shrubs with Sphagnum below.

growing in the water beyond the pioneers, the sedges and the shrubs, was only determined by careful inspection.

It is evident, upon comparing this with the other two lakes described, that this is quite different from either, in the stage of its development, and represents very late steps in the process of which they were early ones.

The nearness of this bog to the railroad, its heavy covering of Sphagnum, and the probable freedom of the peat from objectionable sedimentary matter, make this deposit worthy of further study, with the view to making some commercial use of it, for although it is not of so great superficial extent as some other tracts seem, the moss upon it is unusually good, and the depth of the peat is greater than common.

Completely Filled Lake or Basin Near Nathan.

Considering the bogs as a series, the best example of a deposit which seemed to represent the final stage of the complete closing of a lake by plants was found about 1½ miles east of Nathan, on sections 19 and 20, and extending north and south in Tp. 37 N., R. 27 W. Here, the open water had disappeared entirely, but there was a wet marsh covered with sedges and small areas of Lake Bulrush, which occupied the wettest places, where the water was an inch or two above the surface. Growing with the Bulrush in the water were the Buckbean and the Flat-leaved Bladderwort, and, indicating the approach of the end of the wet cycle, were an abundance of the well established, though small, plants of Sweet Gale, and not a few individuals of the Dwarf Birch, Cassandra, and Andromeda, as well as the Pitcher Plant, growing among the Bulrush stems.

Under one of these wetter places the peat was found to have the following section:

	Feet.	Total depth in feet.
Turf	1	1
Rather soft, poorly decomposed peat	3	4
Sludgy or very watery peat	3	7
Dark colored marl	1	8
Light colored marl	1	9
Sand at bottom		

The marsh around these areas of Bulrush was slightly higher, having the water level about two inches below the surface, and was covered with sedges, of which the Slender Sedge, the Twig-rush, the Alpine Cotton-grass and the Sheathed Cotton-grass, with occasional plants of the Lake Bulrush, were the most important species. There were also a large number of low plants of the shrubs mentioned as occurring among the Bulrushes and here again was found the Pitcher Plant, and small specimens of Tamarack.

The whole surface of this area, except the "islands" described below, could be easily shaken with a relatively slight effort. The "islands" were groups of trees of various sizes which had established themselves upon the open marsh, the principal tree thus appearing upon the marsh being the Tamarack. One of these islands not far from a considerable area of nearly pure lake Bulrush was about 75 feet in length and half as broad. In this area were several Tamaracks, 20 to 30 feet tall, one Black Spruce and one Arbor Vitae, while forming a rather dense growth beneath and around the border of these, were the following shrubby and herbaceous species: In the shade of the trees, were the Labrador Tea, the Sweet Gale, here much larger and taller than in the marsh, the Buckthorn, the Swamp Honeysuckle, the Large Cranberry, the Pitcher Plant and some low sedges. The Andromeda was growing abundantly around the outer edge of the island, but not under the shade, and the Bulrush grew close up to the island, but not in the shade of the trees. The surface of the marsh was no higher where these islands occurred, but the peat seemed somewhat firmer and less easily shaken on them, and the water level was slightly lower, but still less than 6 inches below the surface. There was no Sphagnum on the island described, nor on others, and none over a greater part of the sedge marsh, although near the shoreward margin it was seen in small patches either among the sedges, or more often, about clusters of shrubs.

Around this open marsh, on the west side, was a mature tree-covered swamp, Arbor Vitae, Black Spruce and Tamarack with an occasional White Pine, making the growth. The Tamaracks were the tallest, and presumably the oldest trees in this association, overtopping the other species and appearing of greater age. The ground was covered by Sphagnum and a growth of shrubs, of which the Labrador Tea was the most abundant species, having some Cassandra and the Small Cranberry mixed with it in the more open places. The herbs noted here were the Twin-flower, trailing over the Sphagnum, the Swamp Valerian, the Sweet White Violet and the Kidney-leaved Violet, the Bog Wintergreen, the Three-leaved Solomon's Seal, and the Soft-leaved Sedge. The peat here was 9 feet deep, in places slightly more, firm and structureless below 7 feet. The water level was about 1 foot below the average surface. Quite different was the plant association of the border upon the eastern side of the marsh, where the Black Spruce in a stunted form made up a large part of the tree growth. Here the surface of the bordering zone rose abruptly in many places, nearly or quite 18 inches, as though a wall had been built along it. This wall was of Sphagnum, and marked the edge of a dense growth of the shrubs, Sweet Gale, Cassandra, Andromeda, Dwarf Birch, and Labrador Tea, and occasional plants of the Hoary Willow. The Spruce trees were small, stunted, and were scattered thickly among the shrubs, with a few small Tamaracks and Arbor Vitae, while trailing over the surface of the Sphagnum, or growing in it, were the Creeping Snowberry, the Small Cranberry, and Three-leaved Solomon's Seal. Shoreward from the margin of this Sphagnum and Spruce growth the trees were larger and more numerous than near it, but all had a generally stunted appearance. (Plate XXII.)

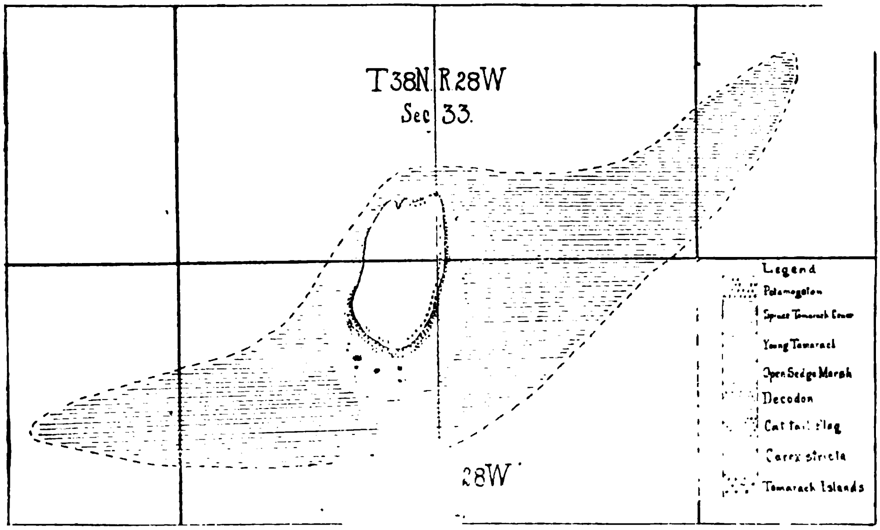
Beyond the general border of the Sphagnum on this side of the open marsh, there were many plants of Cassandra, Andromeda, Sweet Gale and Dwarf Birch growing in the marsh, usually in small dense stools or clumps, and, about some of these clumps of shrubs, as centers of growth, but only occasionally, the Sphagnum would be found established, building up a mound a foot or more above the general surface, and apparently forming an advance colony from the compact shrub-Sphagnum-Spruce association. Upon such colonies of Sphagnum growing around shrubs, the Labrador Tea would sometimes occur, but it was not noted in the sedge marsh except in these elevated spots. These conditions, as described, seem to point to the advance of shrubs and trees and Sphagnum to a rather sharply drawn line which has been maintained for a considerable period, during which existing conditions were constant, and only recently, apparently for only a few years, has there been a change. It seems probable, in the light of what was observed elsewhere, that the sharp border of the marsh with its wall of shrubs and Sphagnum, is the former shore of the pond, which was later covered with sedges and rushes until the present marsh was formed, and that now the surface of this is being covered by trees and shrubs, which under the present stage of rather high water are making slow progress. The absence of the remains of trees and shrubs, and the structure of the turf where this was examined, seem to confirm the opinion that this area had not been before occupied by woody plants, at least not at the level of the present surface.

To the north of the area just described, at a distance of about 200 yards, the tree growth bordering the open marsh was found to be nearly pure Tamarack, under which there was very little Sphagnum, but an abundance of Lesser-panicled Sedge, Small Cranberry, Pitcher Plant, Buckbean and Dwarf Birch, which were the principal members of the association growing beneath the Tamaracks, with which were occasional plants of broad-leaved forms of Andromeda, and Labrador Tea, growing in the shade, and of the Alpine Cotton-grass. Here also were noted the Marsh Arrow-grass, Swamp Saxifrage, Marsh Shield Fern, Sartwell's Sedge, Tall Cotton-grass, Showy Ladies' Slipper, Arethusa and Calopogon. The moss most common with this association was a species of Hypnum, and Sphagnum was not noted.

This Tamarack-Sedge association gradually changed, as the distance from the open marsh increased, to a Spruce-Tamarack-Sphagnum association, and this again near the western margin of the swamp was found to contain a large percent of Arbor Vitae. It would seem probable that the Tamarack covered portion of the marsh border is practically of the same age as the shrub-Sphagnum portion, but in the former, the Tamarack seeded in uniformly and thickly and grew so dense that the shrubs and Sphagnum were unable to establish themselves and have only appeared in the Tamarack association after the trees have begun to thin out, owing to excessive competition of the individuals with each other.

A detailed account of this very interesting bog has been given to show how varied may be the plant associations forming the covering of adjacent areas of the same bog, where there is so slight a change in the level of the surface and the ground water, that only the careful use of a spirit level would enable one to measure it in passing from one association to another, except where Sphagnum has become an important member of the association, and to explain all the peculiarities noted, would require an extended series of observations.

Algal Lake: Of a unique type was a rather extensive bog surrounding a small lake near Merryman's Lake on section 33, T. 38 N., R. 28 W., and section 4, T. 37 N., R. 28 W., and lying in the same basin with it. This lake was in a depression surrounded by low drumlin-like hills covered, in the main, by a hardwood forest, chiefly Beech and Maple, with some admixture of Basswood, Birch, Elm and Hemlock. The present lake is roughly elliptical in form and is only a few acres in extent, but is surrounded by a wooded swamp which is approximately a mile and a half long and which connects with the swampy margin of Merryman's Lake to the northwest. The sketch map, figure 9, shows the approximate shape of the lake and of the swamp surrounding it.



After traversing the Tamarack-Spruce-Cedar swamp for some distance, the northern end of the lake, at which the tree association reaches nearly to the open water, was reached and a most striking fact relating to the marginal zone was at once apparent; it was made up nearly exclusively of the curious Swamp Loosestrife, which, up to this time, had never been observed in the Northern Peninsula, and indeed not far north of the central part of the Southern Peninsula. This plant is worthy of more than mere mention, since it is especially adapted to the lake margin habitat, and also because some of its adaptations enable it to make an advance outward from the shore each year when conditions are favorable, from the position it has been occupying and thus build a mat which will eventually cover the entire surface of the water. The plant is a perennial, forming clusters, or stools, of stems which are herbaceous, and die down each year, above the water, and have curiously thickened woody bases, which live through the winter, below it. The thickening is due in part to an enormous development of spongy, white, or pinkish tissue in the bark, which is supposed to aid the plant to increase the aeration of the submerged parts, since it forms only on parts of the plant below the surface of the water. This tissue is called aerenchyma, and is made up of a multitude of thin-walled cells. The thickening of this part of the stem is also due to actual increase in the diameter of the stem below the water and to a considerable development of hard, woody tissue, so that the real diameter of the stem below the water may be several times that of the herbaceous, aerial parts.

The method of propagation of the plant is also of exceptional interest, for it not only bears and matures large quantities of seeds, but like many other plants growing in and about the water, it has developed a special vegetative method of establishing itself in new places. As they mature, the stems reach out in all directions from the top of the stools and after ascending obliquely to a height of 3 or 4 feet, curve at the tips and turn downward towards the water. Some of these continue to grow downward until they touch the water and reach below it a short distance, after which there is a development of the spongy tissue in the bark, and of wood in the submerged parts, and also of roots, which form in considerable numbers, and may eventually reach the bottom if it is near enough to the surface. From this submerged and rooted tip, buds arise and a new plant develops from these the next season if not before. In the fall the herbaceous or aerial part of the stem is killed by freezing, but the woody part remains alive, moored to the parent stool by the dead stem. This holds the tip with its roots and buds in an erect position, as well as prevents it from being washed away before it has become fairly rooted, and thus a new plant is not only established, but is held in place for a year or more, at a distance of from 2 to 3 feet, or even more, from the shore, advancing the shore line in this way with considerable precision and symmetry. As the plants send out their branches in all directions, some of them do not reach the water but come to the ground shoreward of the stool. These branches may run along the ground for several feet, as many as 6 or more, without becoming woody or forming any roots; such stems perish at the end of the season, so the greatest number of new plants are constantly established on the open water side of the old ones. As soon as the plants set off from the margin of the lake have become fixed in place and begin to increase in size, the water-loving mosses, the algae, the Marsh Shield Fern, and a number of seed plants begin to grow about the roots, and on the stools, and soon reach across to and from the older plants and bind the whole together, at first by a loosely aggregated tissue of stems, but later by a compact turf. In the locality here described, the compacting of the first structure is due to the rapid occupation of this by the shrubs, Cassandra and Andromeda, and by the sedges which soon, or even immediately, are followed by Sphagnum. After the sedges appear upon the stools of the Swamp Loosestrife, the latter plant is apparently unable to persist, for frequently the dead stems and remains of stools may be seen in the sedge marsh behind the zone of living stools at the water's edge.

In the lake under discussion, the Swamp Loosestrife was the chief marginal species around a greater part of the border of the open water, except in two limited areas where the Cat-tail disputed the ground with it, and for a short space on the east side, where the Tussock Sedge formed the margin. The latter plant will probably be displaced eventually by the Swamp Loosestrife, because the Sedge is unable to advance over the water rapidly, building high tussocks or stools by its growth and not a compact turf. The Swamp Loosestrife, therefore, once established among the stools of the sedge, would be able to reach out to the open water beyond them and thus become the marginal plant. At either end of the sedge area, the beginnings of this process of displacement could be observed.

The relatively high level above the water, of the surface of the stools made by the Swamp Loosestrife, affords a chance for a much greater variety of plants to grow than the wetter parts of the sedge mats, hence it is easy to see that after the surface is once covered by the pioneer species, its flora will be more diverse than that of the sedge mat, and will be built up more rapidly to a stage where it will support vigorous tree growth. In this particular instance there was a rather narrow zone just shoreward of the marginal zone in which the surface was higher than that still further shoreward, and upon this young Tamaracks and Sphagnum with several shrubs, such as Cassandra and Andromeda had established themselves, while in the wetter zone shoreward, as is pointed out below, these plants are wanting or are present in lesser amount. It is evident that the Swamp Loosestrife had not been present, at least in this part of the lake, for a very long time, since its remains could only be found in the area where the surface was higher, and this area was in many places only a few feet broad, and nowhere very extensive. The plant is then, one which materially hastens the upbuilding of the surface of a bog as well as rapidly extends it in a lateral direction over an area of shallow open water.

In the areas of Cat-tail near the north end of the lake were numbers of young Tamaracks, which here were growing about at water level, and reached nearly to the water's edge. In most other parts of the bog, young Tamaracks formed a rather dense zone, next to the older tree association, or occurred as mentioned, in small groups along the shore, or scattered in the sedge marsh.

In a small area of open marsh formed by clearing off the old timber, shoreward of the border of the Swamp Loosestrife, the following plants were noted: Sphagnum, Marsh Shield-fern, Cinnamon Fern, young Spruce, Tamarack, Arbor Vitae, Nerved Manna Grass, Blue-Joint Grass, Bristle-stalked Sedge, Three-seeded Sedge, Soft-leaved Sedge, Magellan Sedge, Hairy Wood-rush, Wild Lily-of-the-valley, Clintonia, Calopogon, Buckbean, Bunch-berry, Canada Blueberry, Wild Sarsaparilla, Goldthread, Marsh Marigold, Round-leaved Sundew, Small Cranberry, Small Bishop's Cap, Small Goose-grass, Marsh White Violet, Dwarf Raspberry, Red Raspberry, Star-flower, Tufted Loosestrife, Twin-flower, growing on rotting logs, and Creeping Snowberry, growing on fallen logs and over the top of the Sphagnum mounds. The peat here was firm and moist at the surface, the water level about one foot below the surface, and the total depth of the peat 12 feet. The station was about the only place where the Cedar-Spruce-Tamarack association had reached nearly to the margin of the open water.

Associated with the Cat-tail were quantities of the Marsh Shield-fern, growing slightly above the water level, on the débris of the dead flags, and of the Buckbean, in the water. Scattered plants of Swamp Saxifrage, Marsh Marigold, Marsh Cinquefoil and False Nettle, were frequent, and Swamp Loosestrife and Lesser-Panicled Sedge formed stools here and there in the more open places.

In a rather open part of the Cedar-Spruce-Tamarack zone, was a small pool of clear water, in which grew the Smaller Bladderwort, Water Starwort, Lesser Duckweed, one of the smallest of our flowering plants, Water Arum or Wild Calla Lily, and the Lesser Panicled Sedge. On the margin of this pool were numerous plants of False Nettle, Marsh Shield-fern, and Bristle-stalked Sedge. In the same zone in the dense shade of a clump of young White Cedars was much bare ground, with occasional scattered tufts of Sphagnum, and a few plants of Small Bishop's Cap, Marsh White Violet, Marsh Shield-fern, Wild Sarsaparilla, Goldthread, Clintonia, and Wild Lily-of-the-valley. The mosses were the most abundant type here. The Cinnamon Fern was abundant among the young Cedars, making a striking display with its large tufts of long fronds.

In going east along the north side of the lake, the Cedar-Spruce-Tamarack zone gradually leaves the water margin, while the zone of young Tamaracks becomes wider and the Cat-tail area narrower. Sphagnum follows rather closely the outer borders of the older growth, where it is abundant in the more open places, as far as the lakeward margin of this zone, beyond which it stops abruptly. In this region the Sphagnum is accompanied by Cassandra, Buckbean, and Pitcher Plant.

As the turn to the south is made, a narrow lane, or zone, of open, wet marsh begins, which runs along the east side of the lake to the south end, growing wider as it extends southward, until at the widest part it is several hundred feet wide. This is bounded for some distance on the lakeward side by young Tamaracks and some young Cedars, which here grow close to the margin of the water on the line of low hummocks built by the Swamp Loosestrife. As noted above, the Sphagnum is abundant in the margin of the old tree growth, and also on the hummocks along the water's edge. For a short distance, a portion of this open marsh was covered by Sphagnum, apparently recently established upon it, since the moss was thin and short and the water only a few inches below the surface. Here Andromeda and the Small Cranberry were abundant, the former very short and small, as if lately established.

The Marsh Cinquefoil, a small leaved form of the Buckbean, Pitcher Plant, the Lesser-Panicled Sedge, Mud Sedge, Prickly Sedge, Slender Cotton-grass, Tall Cotton-grass, Scheuchzeria, and the Tall Green Orchis were the only species present, the whole forming a spongy turf. The same species, in about the same relations, as to abundance and water level, were quite generally present in parts of the open marsh where the Sphagnum was not present. The Marsh Shield-fern and Cassandra, conspicuous members of the society bordering the open marsh, were absent from it, and as the level of the surface of the marsh was from 1 to 2 feet lower than that of the Sphagnum-covered borders, it seems probable that the level of the water may be a controlling factor in the distribution of these plants here.

The open marsh continues along the east side of the lake, becoming wider on the south and southwest sides where the Slender Sedge becomes the most abundant plant, giving a different appearance to the surface, because of its uniformly greater height than the rest of the plants with which it is associated. Here at the south end, the zone of Swamp Loosestrife became 20 to 40 feet wide, and the sedge marsh more than 300 feet. The sedge marsh here has Sphagnum and the Small Cranberry over considerable areas, and islands of young Tamaracks and shrubs scattered over it. Where the Sphagnum is not present, the Pitcher Plant, Cat-tail, Buckbean and Marsh Cinquefoil are most abundant, and over much of the area where these plants were abundant, the water rose very nearly or quite to the surface of the marsh. The same type of marsh, though narrower, and nearly the same plants continued toward the north end of the lake on the west side.

Considering now the marginal zone, and the lake itself, the former was chiefly made up of the Swamp Loosestrife, as has been already pointed out. The stools of this plant were frequently so near together along the margin of the water, that they were separated only by a foot, more or less, of open water, and the tops were a foot or fourteen inches or even more above the water; from the top of these stools the growing stems rise, and the diameter of the stools may be more than a foot. Upon these stools the Marsh Shield-fern is one of the first plants to appear after the mosses. Sphagnum, the Cranberries, Cassandra, and the Marsh Cinquefoil, and several species of Sedge were noted as growing upon the newer stools, while the older ones were completely covered by the advancing vegetation of the Cedar-Spruce-Tamarack zone, including young trees of a diameter of several inches. Some of the marginal stools were still isolated from the mat and were easily overturned. The mat, at the firm margin, was about two feet thick, and below this depth, the substratum was a soft light brown ooze, so filled with water that it was practically a fluid.

A study of the relationship of the zones described, led to the conclusion that the Cedar-Spruce-Tamarack zone, with its rather abrupt margin of Sphagnum and shrubs was older than the rest of the bog, and that after this had been developed, a sedge mat had slowly extended itself over the water. At a comparatively recent period, the Swamp Loosestrife had become established on the lake margin and the zone of young Tamaracks, shrubs and Sphagnum had been built up on the stools of this plant, which gave a surface sufficiently elevated above the water to enable these rapid turf formers to establish themselves at once rather than wait for the slow upbuilding of the deposit by the accumulation of the remains of sedges and other water-tolerant plants. The recent appearance of the Swamp Loosestrife is considered probable because of the narrowness of the marginal Tamarack zone.

The description of the lake itself has purposely been left until the last since it presents the most interesting phase of all. The water, seen from the shore, seemed about a foot deep, as far out as it was possible to see. There were no aquatic plants growing in it, except in a narrow zone, some 15 feet wide, close to the shore, which extended about half way around the lake. This zone was made up of plants of a single species of *Potamogeton,* a small, slender form growing only about a foot in length, and making very little show in the water. On sounding, to test the character of the bottom of the lake it was found that it was simply a soft, flocculent ooze, and in collecting samples of this, it was seen to be of a light brownish pink, or pinkish brown color, entirely structureless to the naked eye and hand lens, and of a salvy consistency very different from ordinary peat, even when thoroughly decomposed. A series of samples was taken from the shore of the lake back into the Cedar-Spruce-Tamarack zone, to see if the same type of material occurred beneath these older parts of the bog, as well as in the present lake. It was found that at the margin of the firm turf, the pinkish material was only two feet below the surface; at a distance of 30 feet from the lake it was about 4 feet from the surface; near the middle of the strip of open marsh, from 60 to 75 feet from the water's edge, it was 5 to 6 feet from the surface and just within the Cedar-Spruce-Tamarack zone it was nearly 8 feet down. (Fig. 10.) This station was estimated to be about 150 feet from the water's edge, where the surface of the bog was nearly two feet above the water level. The change from one type to the other was abrupt, and the overlying material was of a dark color and had the usual coarse texture of the upper layers of a bog of the common type.

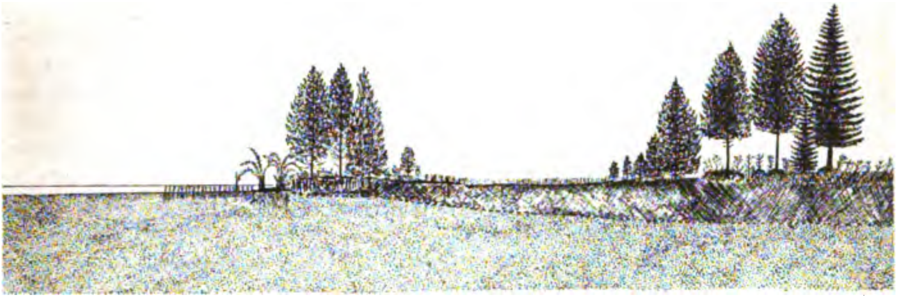


FIG. 10. Ideal section showing the approximate relation (1) of the different types of peat, and (2) the plant societies from the water to the coniferous tree zones at Algal Lake.

The thickening of the coarse material back from the margin of the open water was apparently due (1) to settling of the surface layers, as the weight of the vegetation growing upon them increased, (2) to the upbuilding of the surface above the water level by Sphagnum and other plants, and possibly (3) also to an elevation of the level of the water itself, as the mass of vegetation and vegetable debris upon the surface grew broader and thicker and choked the outlets more and more. It is easy to conceive under such conditions, that the surface of the water would be raised while at the same time there would be a slow building up of the surface of the bog, because of the favorable conditions for the growth of important peat-forming plants, and for the preservation of their remains.

But two small samples of the peat of the lower layers of the deposit and from the lake were preserved for farther examination, but under the compound microscope several important facts were brought out, among which are the following: The material shows the same structure, or lack of it, in both samples; a large part of it seemed to be remnants of minute algae, apparently unicellular forms, with diatoms occasionally or sometimes freely mingled with these. There were no fragments of the tissues of higher plants present and only occasional short segments of the filamentous green algae, but in every slide examined, the most prominent recognizable structures were the peculiar three-celled pollen grains of the conifers, which seemed to have accumulated in vast numbers here. From the fact that there was no greater number of coniferous trees about this lake than many others, where the pollen grains have not been observed in the deposit, it seems evident that they are noticeable here because of the lack of coarser material to hide them and because of the relative small amount of the algal material laid down each year. The pollen grains from 12 feet below the surface, were well preserved and showed as characteristically as those from nearer the surface. Unfortunately, no specimen from the surface of the bottom of the lake was preserved, so that the chief species of algae present were not identified.

The bearing of this observation upon the question of the origin of structureless coals, such as Cannel coal, is worthy of passing mention, for it is apparent that peat of the type under consideration, under proper conditions, would change into a coal which would show little if any structure, no matter how carefully it was examined. The only organic remains which might be identified would be the pollen grains and the silicious shells of the diatoms, just as the spores of some of the Lycopods of the Carboniferous time have been reported as occurring in the European Cannel coal. The possibility suggests itself that, in the Carboniferous age, when all vegetation was of lower types than at present, and the plants now insignificant were then dominant, the simple algae were more abundant, and contributed largely by their activities to the deposits which have since been converted into coal.

Merryman's Lake.

This is a much larger body of water than the small one just described and lies near it. The shores are generally high and there is no extended swamp around it. The water is apparently shallow, for some distance from the shore, as scattering patches of Lake Bulrush extend over a large part of the lake. The margin generally has a narrow zone of the Tussock Sedge and the Slender Sedge. Toward the west end this zone widens, the Slender Sedge being here the most abundant species, forming a broad sedge mat, upon which, however, the Tamarack, Black Spruce, and White Cedar push out to within a short distance of the open water. These trees also form a generally very narrow zone shoreward of the sedge zone, except where fire or man has disturbed the original condition, in which case open ground, or Alder and Willows of various species, replace the conifer zone. In the edge of the sedge zone, on the lakeward border of the conifer zone, near the west end of the lake the following plants were noted in some abundance: The Marsh Shield-fern, abundant, especially on the hummocks about the bases of trees and on sedge tussocks, the Hoary Willow, very common in the marsh, the Marsh Cinquefoil, Calopogon, including a white flowered form, some Cat-tail among the sedges, Arrow-grass, occasional in the same situation; Sphagnum only around the trees, Hypnum more or less common in the wet parts of the marsh. On the hummocks in the marsh, with the Marsh Shield-fern, were the Dwarf Raspberry, the Three-leaved Solomon's Seal, the Cranberries, Hartwright's Persicaria, Creeping Snowberry, Goldthread, patches of Showy Ladies' Slipper, Twin Flower running over logs and stumps, Labrador Tea on hummocks about trees, the Common Horsetail, Bog Wintergreen, the Bristle-stalked and Slender Sedges, a rather common association in the advancing border of the conifer zone. The narrow zone of swamps about this lake, when its water was so shallow, and other conditions were apparently so favorable for swamp formation, is the remarkable thing about it and was not explainable from any facts observed in the limited time devoted to its examination.

Small Lakes Near Merryman's Lake.

In the same vicinity, a small pond was visited which had formerly had a thick growth of Tamarack and Spruce about it, but this had been burned off, and the swamp had grown up to a rather dense thicket of Aspen, common Alder and several species of Willow, with a narrow zone of Cat-tail, Bottle Sedge, and Sartwell's Sedge in shallow water lakeward, with the Lake Bulrush where the water was a foot or more deep. In still deeper water the Yellow Pond Lily formed a nearly complete zone from 20 to 50 feet wide around the entire pond. With the Pond Lilies were numerous specimens of Greater Bladderwort and a species of Water-milfoil, an association common in the Southern Peninsula, but not before seen in the Northern Peninsula.

In Figure 11 the water relations of these plant zones are indicated.

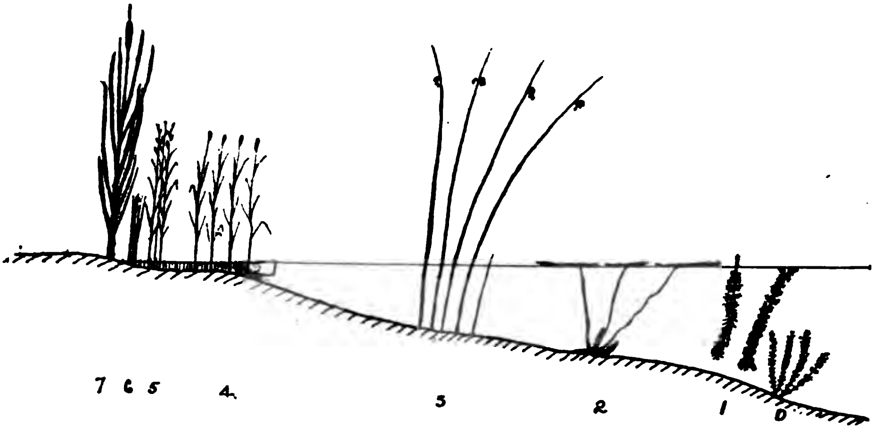


FIG. 11. Diagram of plant zones in small lake near Merryman's lake.

0. Chara.
1. Floating Bladderwort.
2 Yellow Pond Lily.
3. Lake Bulrush.
4. Sartwell's Sedge.
5. Bottle Sedge.
6. Spike Rush.
7. Cat-tails.

In the sedge zone Hartwright's Persicaria, the Larger Blue Flag, Swamp Milkweed, the Marsh Cinquefoil, Joe-Pye Weed, Blue-Joint grass and the Marsh Shield-fern, were the most common plants, with the River-bank Sedge, Shining and Bebb's Willows, Marsh Skullcap, Marsh Bellflower, Nerved Manna-grass, Dark-green Bulrush, and the Swamp Thistle less common, and in the dryer spots the Red-osier Dogwood. This whole association, as will be seen upon comparing it with the others recorded from the vicinity, is remarkably different, closely resembling that found in the southern part of the state in peat bogs which have been partially drained. It is probable that the burning to which this swamp had been subjected made it possible for these plants to find a foot hold here. There was no Sphagnum present so far as observed.

In contrast with this was another swamp a short distance away, with a small lake in it, but which had not been burned over. The swamp was covered with Tamarack and White Cedar, with a few Black Spruces scattered among these, and extending to within about a rod of open water. On the lakeward margin of the coniferous zone, was a narrow zone of Common Alder and various Willows, and then a broader zone of Slender Sedge, which was apparently encroaching slowly upon the lake, since it formed on its lakeward margin, long narrow projections into the open water, which here was quite shallow. In the little bays thus formed the Yellow Pond Lily was established.

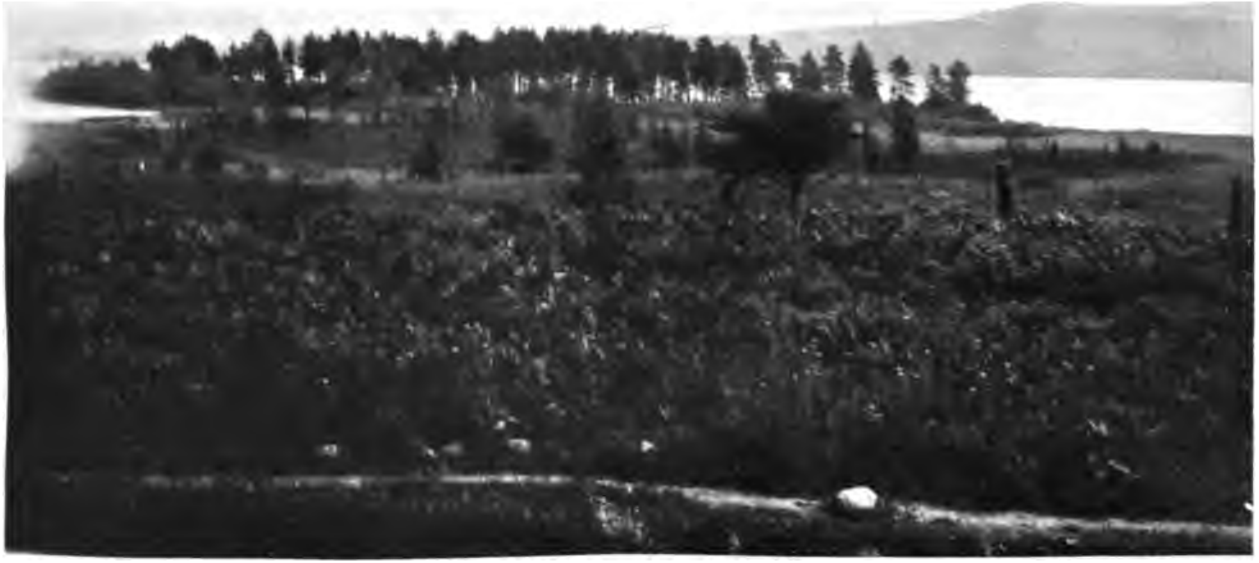
Associated with the Slender Sedge upon the open marsh, were the Hoary Willow, scattered plants of the Cat-tail, the Marsh Cinquefoil, Marsh Shield-fern, Buckbean, and the Shrubby Cinquefoil. The latter plant was most abundant lakeward at the margin of the sedge zone, where, with the Swamp Honeysuckle, it formed in the more open places, a narrow, interrupted zone.

Sphagnum covered occasional spots in the conifer zone, but was nowhere abundant. In the same zone the following species were noted: Spurred Gentian, Twin-flower, Showy Ladies' Slipper, Creeping Snowberry, Buckthorn, Silky Cornel, Low Raspberry, Star-flower, Bog Wintergreen, Common Alder, Yellow Sedge, Labrador Tea, Common Sundew, Small Cranberry, and the Tall Green Ochis. In this lake and swamp it was again apparent that the active plant in covering the open water was the Slender Sedge, aided by the Yellow Pond Lily, which was here able to grow with considerable luxuriance, and, without doubt, contributed considerably to the peat. Here, as elsewhere in this region, Sphagnum was not present upon the wetter parts of the advancing plant zone, nor in the water, but was confined to the older and dryer areas, mostly those in the coniferous zone.

Hermansville Bogs.

(1.) *A mature bog.* In an extensive Tamarack-Spruce-Cedar swamp about a mile east of Hermansville, on Sections 6 and 7, T. 38 N., R. 26 W., and running over into adjoining sections, the Black Spruce was more abundant than usual; the White Cedar large enough for commercial purposes had been cut, but there was some reproduction and young trees of the species were thrifty where seen. Ditches run along the sides of the road east from Hermansville, but they have not drained the swamp to any extent, the water in the ditches being 1½ to 2 feet below the surface and in the swamp from 1 to 1½ feet or 2 feet from tops of hummocks. The removal of the mature Cedar had allowed the light to come in more than usual in such mature swamps, with the result that the shrubs and the other low plant species were numerous and luxuriant in their growth. Sphagnum was also very abundant, forming a quite uniform layer, somewhat uneven at the surface and 1 to 2 feet thick. The shrubs noted here as more or less frequent were the Dwarf Birch, Buckthorn, Swamp Honeysuckle, Hoary Willow, Red-osier Dogwood, Cassandra, Labrador Tea, Andromeda and Dwarf Raspberry; Wintergreen and Creeping Snowberry were found on the tops of the hummocks, the former on the dryest of these, upon which the Reindeer Lichen had established itself. The Small Cranberry was also noted in spots on the Sphagnum, but was not so abundant as this species often is, in similar habitats.

The herbaceous species here, were Slender Cotton-grass, Magellan's Sedge, Soft-leaved Sedge, Bristle-stalked Sedge, River-bank Sedge in de-



Pine "Island," Lake Antoine, near Iron Mountain, showing Spruce, Tamarack, shrub and sedge bogs. Norway Pine on the island: Jack Pine and Common Brake in the foreground.

pressions, Twin-flower, Gold-thread, Swamp Valerian, Marsh Shield-fern, Wild Lily-of-the-Valley, Three-leaved Solomon's Seal, Swamp Saxifrage, Swamp White Violet, Wild Calla, growing in moist Sphagnum, Bog Wintergreen, Small Bishop's Cap, Showy Ladies' Slipper, Manna-grass, usually in the wetter places, and the Bunchberry on top of the dryest hummocks, with Reindeer Lichen and Wintergreen. Along the road, and in larger openings, were numerous specimens of Common Alder, often forming dense clumps, but this species was not seen in the less disturbed parts of the swamp and seemed to be a clearing plant where it was present.

This section is represented by the diagram, Fig. 12, below.

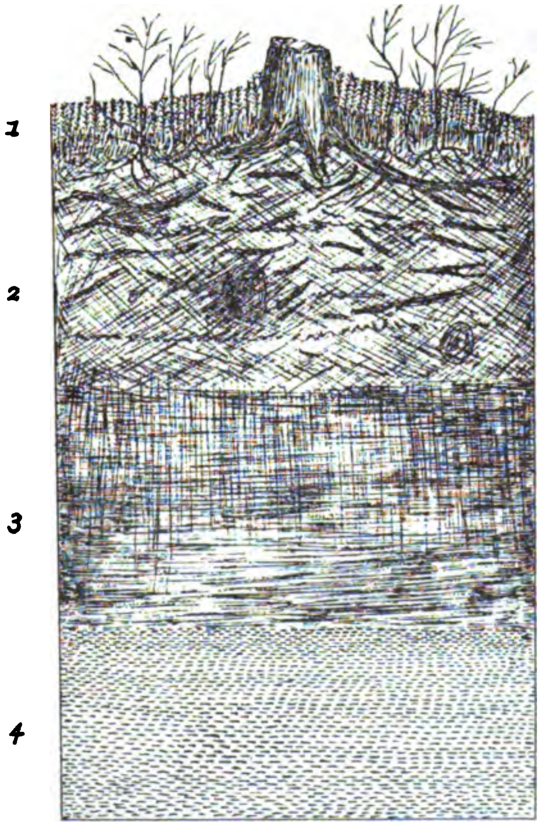


FIG. 12. Section through a mature peat deposit near Hermansville, Menominee county.
1. Surface vegetation.
2. Layer containing roots and coarse vegetable debris.
3. Fully decomposed dark peat.
4. Light colored structureless peat.

The peat was tested near the middle of the swamp, where it was crossed by a road and was about 14 feet deep, the first 5 feet being rather coarse textured and full of roots, fallen logs, etc. Below this for 5 feet it was brown in color, of good texture and quite plastic, while the lower 4 feet were soft and light colored, suggesting the algal peat described above, in color and texture.

Apparently the upper 5 feet of peat had been deposited since the trees and shrubs had established themselves in the swamp while the lowest parts of the deposit seemed to have been formed under water, as the light color of the material precludes the idea of thorough decomposition, since that not only disintegrates the material but blackens it at the same time, often in proportion to the completeness of the decomposition. This deposit was in a poorly drained valley in the drumlin region, and represents the mature type of swamp for the region, except that the flora was rather richer than usual, because of the removal of the Cedar. There was no indication here or elsewhere in the region of the drumlins, so far as observed, of this type of swamp plant association passing into any other tree society, and it seems probable that it is a climax society for the habitat.

(2.) *Cleared Bogs:* It was unusual to find any of these mature peat deposits which had been cleared with a view to cultivating them, but just west of Hermansville, in the depression between two large drumlins, was a small bog which had been ditched and stumped and cultivated for two or more seasons before the owners decided that the soil was not adapted to crop plants, and when visited, was reported not to have been plowed for several seasons, and so it had begun to revert to the wild state again. Some of the cultivated grasses and clovers had established themselves in the loose-textured dry peat, and were growing well; the native plants found persisting, or introduced since the land had been abandoned, were the Common Aspen, Labrador Tea, Cassandra, Canada Blueberry, Bristly Sarsaparilla, The Wild Red Cherry, and an occasional small Tamarack. The herbaceous plants besides the cultivated species mentioned, were the Common Brake, Sheathed Cotton-grass, Few-seeded Sedge (rare), Three Seeded Sedge, forming low stools, the Three-leaved Solomon's Seal, Sheep Sorrel, Great Willow-herb, while in many cases the ground was covered by a dense growth of the Hair-cap Moss, the same, or closely related, species that was found commonly on very dry, sandy soil, or in crevices and on ledges of exposed rocks. The loose texture of the partly decomposed plant remains making up the top layers of this bog, and the drought-resisting or xerophytic character of most of the native plants growing upon it when visited, as well as the depth to the water table, more than 2 feet, in the ditches, point to insufficient or unavailable supply of moisture as an important factor in rendering the ground unfit for cultivation until farther decomposition has compacted the peat and lowered the surface.

Undoubtedly, also, the small amount of mineral food available for plants, as well as other considerations would need to be taken into account in working out all of the contributory causes of failure of crops on the area. At the time it was visited it gave every indication of becoming a brush swamp in a short time. It was reported to have been covered with Cedar before it was cleared.

Bogs Near Faunus.

Near the northern limit of the drumlin region, southeast of Foster City, along the line of the Chicago and Northwestern R. R. is a considerable district in which limestone ledges lie very near or at the surface. These exposures are flat, which makes the surface of the ground level and the drainage poor. These flat surfaces of limestone with thin soils were formerly often covered with Cedar-Tamarack-Spruce swamps, from which the valuable timber has been stripped. Following the lumbering, fires have destroyed some of the remaining trees, but many of the areas still show swamp conditions in the vigorous growth of young Tamarack and Cedar. It is a noteworthy fact regarding these swamps, that the peat upon them is generally very thin, coarse in texture and poorly decomposed, so that here, as elsewhere, the top of even the shallow deposit is often very dry.

It is an interesting fact, also, that in many places where there were well-developed swamps, the rock was so near the surface that telegraph and telephone poles were held in place by stones piled about the bottom, because holes could not be dug sufficiently deep to hold the poles in the shallow soil. Generally in such areas the peat was not more than 18 inches deep and frequently less than this, and was covered, in the burned-over tracts, with a dense growth of Alder, Willow and Poplar, or by young Tamarack, or less frequently, by young Cedar and Tamarack mixed. The flatness and impermeability of the rock surface seem to be the controlling factors in developing these swamps, since they tend to keep the ground water level high. The thin layer of till which may lie below the peat and above the rock surface is usually gravelly and serves to store some of the water which falls on the surface.

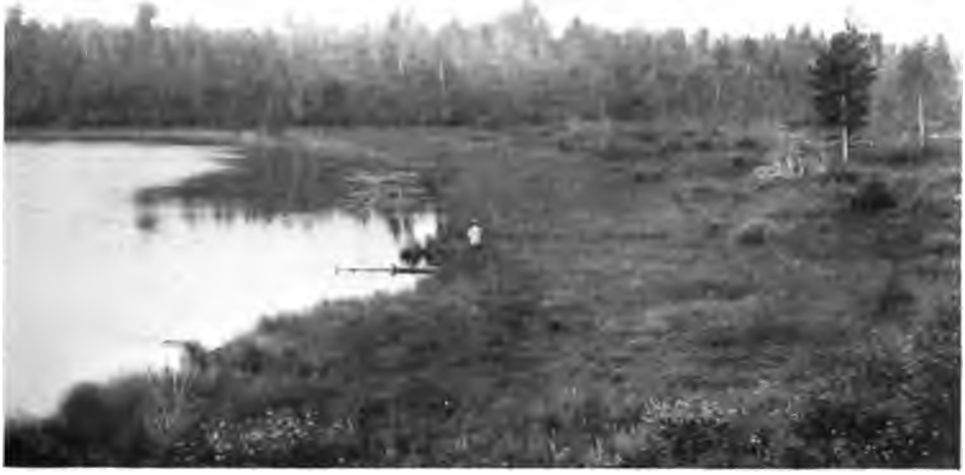
In T. 41 N., R. 26 W., between the water tank on the C. & N. W. R. R. and Faunus station, is a valley swamp bordering a small sluggish stream flowing into Ford river, which gave some exceptionally interesting opportunities for the study of the tolerance of water exhibited by bog plants. The valley was very shallow and the slopes slight, so that drainage was very poor over most of its bottom, which had been covered by a mature Cedar and Tamarack forest before it was disturbed by lumbering and fire. In crossing the swamp, on sections 19, 20, 28 and 29, much of the material for grading up the road bed of the railroad had been dug from the right of way on either side of the grade, leaving shallow ponds and broad ditches in which the water stands to a depth of 18 inches or 2 feet below the surface of the peat on which most of the species of shrubs and perennial herbs of the mature Tamarack-Cedar-Spruce association were growing. These plants, since many of them propagate by underground stems, have grown out into and over the ditches and ponds, until these have been nearly filled up in some places. In a few instances the growth covering the surface of the water was of mosses, chiefly species of *Fontinalis* and *Hypnum*, but in one instance *Sphagnum* seemed to be the form, although the plant was seen from a distance, and the observation is uncertain. A higher type of plants was represented in the Pond-weeds, which are true aquatics and may have been introduced into the ditches from the stream or from a distance by birds or other animals. The plant which was most effective in covering the open water, however, was the Marsh Cinquefoil, which sent out long branches from the sides of the ditches and ponds and often completely covered the surface for some distance. This species was never observed by the writer as the marginal plant over considerable areas along the shores of lakes, but here, around the artificial openings in the turf, it demonstrated its fitness to serve as the advancing plant in open water by forming dense mats, which soon serve as a basis for growth of a number of species of sedge, especially the Creeping Sedge, and for the Wild Calla and a species of *Hypnum* moss. The Marsh Cinquefoil is apparently killed by the encroachment of the Sedge, as, where this was present, the first plant was not as luxuriant as where there was no admixture of other species.

Next to the Marsh Cinquefoil, Andromeda was most frequent in its extensions into the water from the sides of the ditches, and long, rootless branches, 2 to 3 feet, or more, long, reached out into the water, often with only the tips of the terminal leaves above the surface. This plant did not form extensive mats, as the number of individuals along the sides of the ditches was not large in any one place, but the subaqueous shoots were normal and vigorous, and, in time, would serve as the basis for attachment of other species. Cassandra was also abundant, growing in the water in the same way as Andromeda and because of its more compact habit of growth, it was perhaps more frequently the center of development of small islands of other plants, which eventually became joined permanently to the bank of the ditch, and thus formed solid land. Other shrubs which extended out over and into the ditches and pools from the banks, forming more or less compact mats, were several species of Willows, the Dwarf Birch, Alder, and the Buckthorn.

Of herbaceous plants, the Creeping Sedge was found most frequently, forming extensions from the banks, both alone, and as an associate of other species, sending out horizontal, cord-like, leafy stems sometimes 4 feet long, either in the water or over the surface of areas filled by floating moss. This sedge does not form a compact mat, as it forms roots rather infrequently along the prostrate stems, but it serves to bind other species together when its strong stems are overgrown by them.

The Wild Calla was doing similar work, extending its thick, freely rooting, prostrate stems, which bear numerous broad leaves and large flowers, in dense masses from 3 to 6 feet wide, out from shore on a substratum of moss, floating in the water. The plant thus forms a foundation for other species, and at one point the following species were growing with it: The Porcupine Sedge, forming small tufts, the Marsh Skullcap, the Great Water-dock, Blue Joint Grass, a Willow, the Small Bedstraw, and the Bulb-bearing Water Hemlock, a small part of a common open wet marsh society in which usually some species of Sedge is the dominant plant.

Other herbaceous plants which were noted as forming extensions from the shore in the pools were the Cat-tails, Hartwright's Persecaria, and, more rarely, the Buckbean. Growing in the water with the Pondweeds, were the Lesser Bladderwort, Pursh's Buttercup, and a very slender form of the Broad-leaved Arrowhead, while the Swamp Horsetail formed dense masses in some pools, rooting in the peat in a foot or more of water. It appears from the considerable variety of types of plants in this artificially formed habitat, in a locality where the number of species is rather restricted, that for a time, at least, those species which are present and establish themselves first are the ones which are able to occupy the space, but that later, other types come in, and wholly, or in part, dispossess the pioneers.



North side of small lake, near Bad Water Lake, showing: (1) Thin zone of Pond Lilies in shallow water; (2) Narrow zone of Sedges on a gently sloping shore, making a thick turf on sandy bottom; (3) Cassandra and other shrubs forming thick growth up to the higher ground; (4) Background of Norway Pine and White Pine. The area shown in Plate XXV is at the extreme left of the picture.

Bogs in Sand Plain Near Vulcan.

The first bog visited in the morainal region was in an extensive sand plain south of Vulcan in T. 39 N., R. 29 W., Sec. 15. The bog was a small one in a depression without outlet in the sloping sand plain and was originally surrounded by a forest of nearly pure Norway Pine, now represented by a remnant of a few acres in extent, on the south side of the depression. There was no open water upon the surface of the bog, but it was an excellent example of a type which is perhaps our nearest approach in Michigan, to the European "Hochmoor." In the middle of the bog was an irregularly elliptical tract in which Cassandra was the dominant plant, but with some dwarfed young Tamaracks, a single dead Norway Pine, and some dead Tamaracks of larger size, as well as Andromeda, Pale Laurel, Small Cranberry and the Slender Sedge. The surface here was built up by Sphagnum to about a foot above the water level, around the clumps of the Cassandra, and other shrubs, but this high level was not maintained uniformly, as there were numerous depressions reaching the water, where the Sphagnum had not yet grown as high, in which the Pitcher Plant, Buckbean, and Mud Sedge were common. Shoreward of this raised portion, was a broad zone of apparently pure Slender Sedge, but associated with it, on closer inspection, were found the Marsh Cinquefoil, the Myrtle-leaved Willow, and in the border next the elevated portion, and on the south side of it, Sphagnum growing in the water. On the north side, however, there was no Sphagnum with the Sedge. The water was from 1 to nearly 3 feet deep in this zone and the bottom easily shaken. Nearer the shore, the water was uniformly about 18 inches deep and in this part of the zone the Nerved Manna-grass, Tall Cotton-grass and Marsh Cinquefoil were generally present in abundance. This zone extended shoreward nearly to the water's edge, and merged into a well-defined but narrow zone of Blue-Joint Grass, and this, in turn, into another of Meadow-Sweet, about a foot above the water level, and above this, Alder formed a dense zone to about 3 feet above the water level, above which the Norway Pine association began abruptly and covered the slopes. The chief variation in this zonation was, at the east end, where the Cat-tail formed a partial zone shoreward of the Slender Sedge, and the replacement of the Norway Pine by pasture and cleared-land societies on the north and west sides of the valley. The very considerable depth of water in which most of these bog societies were growing, 2 feet, and more, in parts of the sedge zone, seems to indicate a recent rise of the water level, due to excessive rainfall, and it is probable that most of the zones were established in a time when the water was lower than at present, and, except the trees, have persisted during the rise, which would be very rapid in an enclosed basin of this type; the dead Tamaracks and the Norway Pine would indicate such a rise in the water, as trees are more often killed in this manner than the more tolerant sedges, grasses and other herbs and shrubs. A fire sweeping across the swamp would also destroy the trees, and not, necessarily, the herbs and shrubs, but no marks of fire were observed.

Other Kettle Hole Bogs Near Vulcan: A group of small depressions a mile south of the one just described, form an interesting series. The depressions were four in number and situated in Sec. 22, T. 39 N., R.

29 W., near the border of a portion of the gravel plain mentioned above, which had been cleared and cultivated. The larger one of the series had a small pond in it, which was surrounded by a wide quaking bog covered largely by shrubs and sedges. The water in the pond was shallow and had the Yellow Pond Lily scattered over nearly the whole surface, while near the shore there was an interrupted zone of Creeping Spike-rush pushing out towards the center and a mat of Slender Sedge following it. Upon the sedge mat were scattered plants of Dulichium, Scheuchzeria, Buckbean, and Marsh Cinquefoil, and also islands of Cassandra at distances of from 20 to 50 feet from the edge of the open water. Upon this part of the sedge mat the water was about a foot deep, and in the water was an abundance of Hypnum moss, which, near the shoreward margin of the sedge mat, was more or less displaced by submerged Sphagnum. In this part of the mat also were found the Marsh St. John's-wort and the Bulb-bearing Water Hemlock.

Still nearer the shore, the surface rose a foot above the water level and the shrub-Sphagnum zone proper began, though the whole mat was still easily shaken. The plants of this association were Cassandra, Andromeda, Large and Small Cranberry, Tamarack, White and Norway Pines, the latter upon the stools formed by stumps of dead trees, the Tall and the Virginia Cotton-grasses, the Mud Sedge, which was here abundant, Marsh Cinquefoil, Pitcher Plant, Buckbean and Round-leaved Sundew. The presence of old stumps of considerable size in this zone shows that formerly this part of the bog was more heavily wooded than now, but the cause, other than clearing, of the disappearance of the trees was not apparent. Shoreward, near the margin of the bog, was a zone above the water level, of Blue-Joint Grass, with Silky Willow, and Meadow-Sweet, scattered through it. The River-bank Sedge and Nerved Manna-grass were common here in slight depressions. Still farther shoreward was a well-developed zone of Common Alder which covered the bank nearly up to the zone of cultivation.

The second depression was much smaller than the first, and was in the open shrub stage of development, i. e., the shrubs, chiefly heath plants, were the dominant types; the entire surface was covered by a dense growth of Cassandra and Andromeda. Among these plants there were a few large stumps and numerous small ones, showing that rather recently the shrubs had been dominated by trees, at present represented by a single small White Pine, a Tamarack and some White Birches and Common Alders growing on the hummocks around the stumps noted above. In small open depressions below the general level were sedges and patches of Larger Blue Flag. The water level was generally a little over a foot below the surface in this part of the bog. Shoreward of the shrubs was a zone of lower water level, covered chiefly by the Larger Blue Flag, but with it were the Tussock Sedge, Blue-Joint Grass, Cat-tail, Alder, and several species of Willow. Next to the shore and running up on to it, was a zone of Wool-grass, Nerved Manna-grass, Larger Blue Flag and Soft Rush, which reached up to more than a foot above the surface of the water.

The third depression was elliptical in shape, 30 feet wide by 70 feet long, and had in the middle a small pool of water about 10 feet in length, in which were a few plants of the Yellow Pond Lily and a small patch of Lake Bulrush. Around the pool was a dense growth of Cat-tail covering all of the bottom of the depression except for a narrow zone on the shoreward margin, which was covered by a growth of Wool-grass and slightly above this a zone of the Nerved Manna-grass and Larger Blue Flag.

The fourth depression was covered by a dense growth of Common Alder and Willows.

The bogs in this series show the effects of clearing and burning, in the disappearance of large trees from the larger básins, and of all the trees and plants of the mature bog societies from the smaller ones, so that the cycle of development in these has begun anew with water plants. In the larger ones the building of the sedge mat was apparently not interfered with, but the disappearance of the trees caused the shrub society to expand to a much greater width than would be possible under undisturbed conditions. The series well illustrates the influence which man has locally upon the distribution of plants.

Lake Near Menominee River, South of Norway.

In the same section with these bogs in the cleared and cultivated area, was an interesting kettle-hole lake, located on the terrace of Menominee river. The water of the lake was at the same level with that of the river and was connected with it by a short broad outlet, so that the river, in time of flood, caused a sharp rise in the lake and as abrupt fall when the flood was over. On the zone of the lake bank which was thus alternately covered by water and exposed to the sunlight and the air, was a society of plants which is frequently found in the flood plains of the rivers in the Southern Peninsula, but which is not common in the Northern, where the river swamps have not usually been cleared, and where the mature Tamarack-Spruce-Cedar society is the one in possession of such places, except the more recently formed bars or areas of sediments. The principal plants noted in this society were the Sensitive Fern, River-bank Sedge, Slender Rush, several species of Willows, Common Smartweed, Canada Anemone, Purplish Meadow-rue, Yellow Watercress, Meadow-Sweet, Marsh Pea, Upright Yellow Wood Sorrel, Canadian St. John's-wort, Spotted Cowbane, Bulb-bearing Water Hemlock, Swamp Milkweed, Blue Vervain, Hedge Nettle, Cut-leaved Water Hoarhound, Wild Mint, Monkey-flower, Joe-Pye Weed, Late Golden-rod, several species of Aster, Sneeze-weed, and Philadelphia Flea-bane. The soil here was mostly composed of fine silt, or river sediment, and was moist over the entire slope. The absence of characteristic bog plants is of interest and may be due in part to the clearing which has been done, since in a similar bayou-like lake in another place, some bog plants were noted upon the banks of the lake. A view of a portion of this lake and the connection with the river is shown in Plate XII of Prof. Russell's paper, page 57.

Lake Antoine, a Large Basin Beginning to Fill.

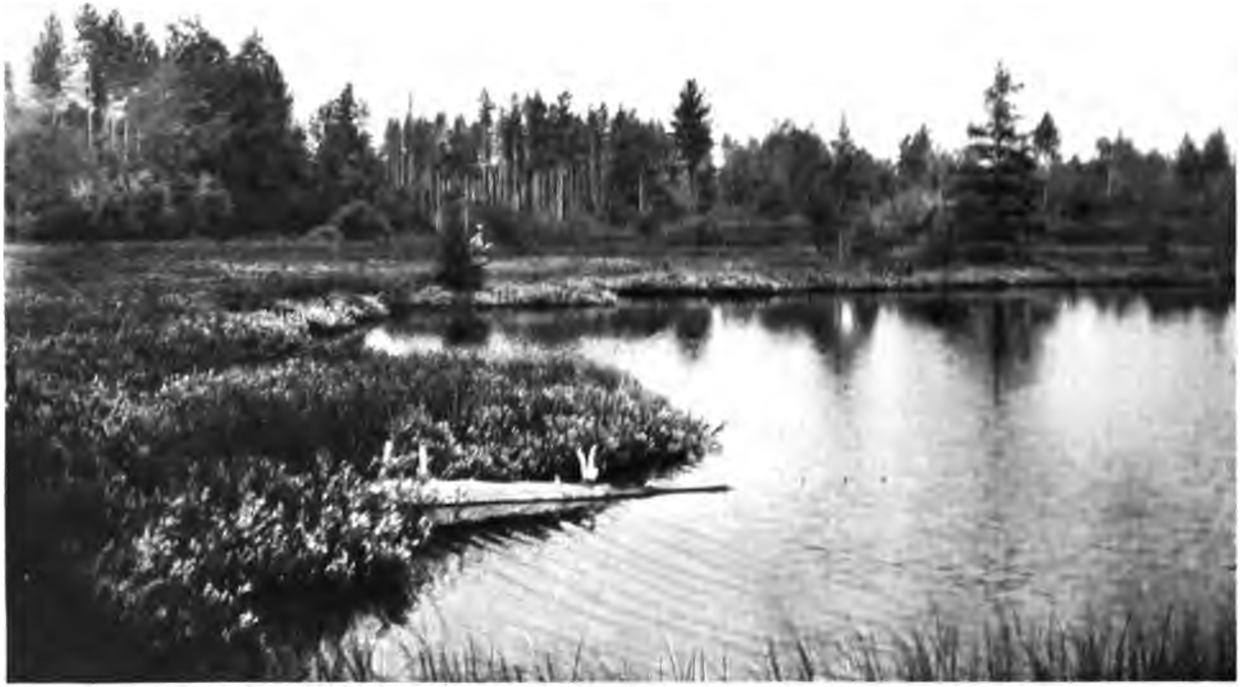
This is a large lake with no inlet and small outlet a short distance northwest of the city of Iron Mountain, T. 40 N., R. 30 W., covering parts of several sections. There is little true bog existing around its shores, a large part of which are high and dry, with a rather steep slope. The lake is mentioned here because of a series of small bogs which exist along the north shore in coves on the west sides of points, and behind an island on the northwest side of the lake. The most remarkable of these bogs is the one connecting Pine Island (Plate XXIII), as it is called, with the mainland, making a peninsula of it. The island lies some hundreds of feet from the shore, the entire space between being occupied by the bog, which is prolonged beyond the island on the western end, and has a well-defined cove at the eastern. Upon the bog are two distinct areas of mixed Spruce and Tamarack, surrounded by typical Sphagnum-Cassandra-Andromeda zones. The borders on all sides are covered by a sedge mat, in which the Slender Sedge is the chief plant, forming a belt from 200 to 300 feet wide. The aquatic plants form two distinct zones outside of this; the lakeward one, where examined, made up chiefly of Pondweeds, of which the Common Floating Pondweed is the most conspicuous and abundant, while next the floating margin of the sedge mat was a zone of varying width, made up largely of White and Yellow Pond Lilies.

The Cat-tail and Dwarf Birch are present in small areas upon the sedge marsh, and the Marsh Cinquefoil forms good-sized patches in places near its margin. The fact that there are two centers of tree growth, and a wide open space extending for a considerable distance between them, would lead to the conclusion that there have been two distinct periods of filling here. The first of these was the time during which the western part was being built up in the shelter afforded by the island, and the other, after the bar thus built had diminished the depth of the water between the island and the shore so much that plants could grow in the water and hold such floating débris and sediment as drifted into the cove thus formed, and this material finally became a center of growth of the bog.

In the coves lying east of the island bog, there are shown several steps in the formation of bogs upon the shores of a large lake. In the first one east of the island, the marginal plant extending over the water was the Slender Sedge, forming a floating bog upon the edge of which were spots of Cat-tail, while upon the bog were some small Spruces and Tamaracks, Alders and Willows, with small areas of Cassandra and Dwarf Birches, and more abundant, the Marsh Cinquefoil, and Marsh Shield-fern. The margin of the mat was entirely free from the bottom, with nearly a foot of water above the surface, and upon this grew small Pondweeds, the Swamp Persicaria, and Greater Bladderwort. In some cases small fragments of the border of the mat, a foot or more across, were free from attachment to it, and formed floating islands, which were moved about by the waves.

In another small marshy area on the west side of a point still further east, the Slender Sedge and the Marsh Cinquefoil were still the dominant plants, but the Lake Bulrush was present in small quantities, and near the landward border of this, as well as the other mentioned above, the River-bank Sedge and the Blue-Joint Grass were of frequent occurrence. There were no aquatic plants noted beyond the margin of the sedge mat here.

The location of all of these bogs on the western side of protecting land masses, and the fact that the eastern sides of these were being washed so strongly that the shores were covered by coarse gravel and boulders, with no vegetation near the water's edge, indicate the existence of a



Western margin of the same lake as Plate XXIV, showing: (1) Absence of aquatic plants; (2) Andromeda, the whitish shrub, growing in and over the water; (3) Cassandra, the darker shrub, forming a mixture near the water, but pure near the shore; (4) Scattered Tamaracks near the water's edge; (5) Norway and White Pine on higher ground.

prevailing current down the lake upon the north side. This current is most probably set in motion by the westerly winds, blowing the water towards the east end of the lake and heaping it up there, whence it returns to the west end again, in part at least, along the north shore, and the island and points mentioned have small eddies on their western sides, which favor deposition of drift material, silt, etc., carried to them by this westerly current, and this, in turn, encourages the growth of plants which have built up the bogs. No soundings were made here on account of the small size of the deposits and the apparent weakness of the sedge mats, but the water below the margin of the sedge mat was probably at least 6 feet deep.

Sphagnum Bog Near Lake Antoine, Iron Mountain.

On Sec. 20, T. 40 N., R. 30 W., a short distance north of Lake Antoine, was a small bog with some features of special interest, especially in the fact that there were stunted White, Norway and Jack Pines growing in the more open parts, besides Tamarack and Black Spruce, also much stunted. Around the shoreward margin, and especially at the northern end, where its width was greatest, was a dense growth of Balsam, Black Spruce and Tamarack with occasional White Pine forming a zone of variable width around the open part of the bog. This was irregularly elliptical in shape with a small pond of open water near the northern end, and was covered by a shrub-Sphagnum society, and the partly consumed stumps and other remains of trees, showed that fire had run over the surface at some recent time and destroyed the mature trees. The water level, at the time the bog was visited, soon after a heavy rain, stood from 1 to 2 feet below the top of the Sphagnum mounds among the shrubs, but was above the surface in depressions.

The water in the pond was more than 5 feet deep off the overhanging edge of the bog, and had no aquatic plants in it except a few plants of the Yellow Pond Lily, which grew so close to the margin that it was not possible to determine whether they grew from under the edge of the bog or not.

The marginal plants here presented a new and most interesting departure from the usual order of advance; the possibility of such a variation had been suggested by the conditions existing at Nathan, and in a more marked degree in the railroad ditches near Faunus. The whole border of the pond was fringed by a zone of shrubs, Cassandra and Andromeda predominating, 10 to 20 feet wide and pushing out into the open water. Of the two species, Andromeda seemed to be the more abundant and more vigorous grower here, frequently occupying considerable spaces and growing out into water several feet deep, for 4 feet or more, with no apparent connection with the bottom. The Cassandra, on the whole, was nearly as frequent in the water as Andromeda, and in one place was seen sending out horizontal, partly submerged branches 6 feet from the shore, in water between 3 and 4 feet deep, but the plant grew taller and larger back from the margin and seemed more thrifty in the dryer parts of the bog, while the Andromeda was neither as abundant nor as thrifty in such places as it was nearer the edge of the water.

After the shrubs had pushed out into the open water in this way and formed a fringe of branches, often other plants would find a foothold with them and would thus build small hummocks. Sphagnum, as would be expected, was one of the first plants thus to take advantage of the chance to extend its range and was to be seen in various places very near the water margin of the shrub growth, but never at it or in open water beyond. With the Sphagnum, a number of other plants were able to grow, including the Small Cranberry, which often followed the Andromeda out into the water without the moss, supporting itself on the stems of the larger and more rigid plants and making a very thrifty growth in such places. Other plants found growing with the marginal shrubs and Sphagnum near the edge of the water were Buckbean, the Round-leaved Sundew and Mud Sedge, but none of these were found advancing beyond the Sphagnum. The association formed a border a foot above the level of the water in its highest parts, but on its shoreward edge the surface was lower, scarcely rising above the water level, over a zone from 10 to 20 feet wide. In this zone, the shrubs were fewer, and there was little if any Sphagnum; the most abundant plants here were the White Beaked-rush and the Mud Sedge, which gave the zone distinct character.

This merged abruptly into the mature Heath-Sphagnum zone, which presented fewer peculiarities, except that in places there were quite extensive patches of the Pale Laurel and where there were trees or stumps, the Sphagnum mounds were built up to a height of 3 feet, or more, above the level of the water. On top of these mounds was found Labrador Tea, which did not grow on the lower ones nor on the sides of the higher ones. The same plant was found in the edge of the well developed Conifer zone, on the shoreward margin of the bog, growing on top of the highest Sphagnum mounds in the shade of the trees.

Other plants in this Shrub-Sphagnum association were the Creeping Snowberry, Small Cranberry, Sheathed Cotton-grass, Virginia Cotton-grass, Few-flowered Sedge, here very abundant, and in the wetter places, near the lakeward border of the zone the Pitcher Plant was very common.

The swamp-conifer border of the Shrub-Sphagnum association was found to end abruptly on the landward side in the thickets of pines which came down the slopes around the bog, except in places where there was a narrow line of Common Alder between them in a shallow trough-like depression, in which also grew the River-bank Sedge. The most common species of pines in the highlands around the depression was the White Pine, but the Jack and Norway Pines were also very frequent and making rapid growth.

In borings near the margin of the lake, the water was found to extend under the mat, to a depth of about 7 feet, below which the peat was coarse and loosely compacted down to 11 feet, where wood was found. At a distance of about 75 feet from the north side of the pond, the peat was compact from 3 feet below the surface down to about 9 feet, where fine clay was reached. The peat was brownish and rather coarse in texture, until near the bottom, where it became rather finer, but not darker in color.

The fact that this bog had been burned over had undoubtedly disturbed the relations of the plants to a certain extent, but this was not the cause of the peculiar lack of a sedge zone next the water margin.

as that would be the area to be least affected by fire. The bog was one of a number of similar ones which, as will be shown later, constitute a distinct type, in some of which, at least, no recognizable disturbance has occurred, except such as may have been brought about by natural forces, operating in the usual and general way, such as periods of prolonged drought, or cycles of wet weather, which occur in all regions at intervals.

Mature Valley Bog Near Granite Bluff.

But few mature bogs were examined in this region because of the lack of variety among them, since they were either usually Tamarack-Spruce-Cedar associations, or more rarely, covered with nearly pure Black Spruce, associated with Sphagnum and shrubs, in which the Spruce was usually very much stunted and more or less scattered. A swamp of this type was examined on Sec. 21, T. 41 N., R. 30 W., near Granite Bluff, on the Chicago, Milwaukee and St. Paul R. R. The swamp occupied a valley and extended a considerable distance in either direction (towards the east as far as the railroad), from the part examined, and, as far as seen, showing the same characteristics.

The Black Spruce was the dominant tree species, but was poor and stunted in appearance, and formed a very thin growth, below which was a heavy covering of Sphagnum, with dense Cassandra and Andromeda. As is usually the case, the surface of the Sphagnum was uneven, built up in mounds 18 inches to 2 feet high above the water level in places, and with relatively bare spots or depressions in others. Upon the mounds were the Labrador Tea, Sheathed Cotton-grass, Three-leaved Solomon's Seal, Pale Laurel and Small Cranberry, and more rarely, the top of a mound was covered by the Hair-cap Moss, which, for the time at least, ends the work of the Sphagnum in upbuilding, since the other moss is able to kill it out, when once it is established upon it. In crossing this swamp from one side to the other, the surface was level and the plants named were the only ones seen, until near the shores. These had formerly been covered by a pine forest, and common plants near the foot of the slopes from the higher ground were Sweet-fern, Hair-cap Moss, Canada, Dwarf and Low Black Blueberries, Bunchberry, Wintergreen, Goldthread and Trailing Arbutus. These plants, except Sweet-fern, also grow in the Sphagnum on the margin of the swamp, while the Creeping Snowberry and Mountain Holly were also found in this habitat. On the other hand the Labrador Tea was found more than 2 feet above the water level, the Cassandra, the Black Spruce and Pale Laurel all were found growing in mineral soil above the Sphagnum, some of them competing successfully with Sweet-fern for space; the fires following the clearing of the pine probably affected the composition of the plant societies of this marginal area in a marked degree, but if so, their effects have nearly disappeared, since the peat along the borders of the mineral soil seemed never to have been burned, and there were few if any charred stumps upon the borders of the swamp. The main effects of the burnings were seen on the higher ground and in the absence of pines from the sides of the valley. If these had been present, the plants requiring much light would have been absent from the marginal area.

The peat in this swamp was about 9 feet deep, half way across the valley, in the places where tests were made, and for about 4 feet from the surface was filled with logs, and the roots and branches of trees and shrubs and such coarse plant débris. Below this depth the structure was finer, but even at the bottom of the deposit it was not well decomposed, although the color was quite dark. Below the peat, the bottom was moderately coarse, whitish sand.

Badwater Lake, North of Iron Mountain.

While this is not a peat-bog lake, some interesting phases of peat formation were observed here which were not found elsewhere, and a brief account of them is not out of place here. Badwater Lake is a small lake about 5 miles north of Iron Mountain, and is situated on Sec. 1, T. 40 N., R. 31 W., in a depression which is connected by a wide, bayou-like outlet, nearly one-half mile long, with Menominee river, so that the water of the lake rises and falls with the river, at least in times of flood. This leaves a space from 3 to 4 feet above the level of the lake in ordinary stages, which is flooded periodically but which receives little silt from the river because of the distance from the stream to the lake. Upon this flooded area was a dense growth of shrubs and such trees as Balsam Poplar, White Ash and Willows. The most common shrubs were the Winterberry, Red-osier Dogwood, Common Alder, various species of Willows, Meadow-Sweet and Sweet Gale, the latter a plant usually found in much wetter places. The bush swamp widens out along the outlet and here, on the margin of the water and growing out into it, were the Creeping Spike-rush and Sweet Flag, making a broad zone of marsh, in which were growing the Marsh Cinquefoil, the Swamp Persicaria and a species of Horsetail. Beyond this unusual association was a zone of Yellow Pond Lily and Pondweeds. At the northern end of the lake the aquatic plants were much more abundant than elsewhere and covered considerable areas. From the relationship of the shrubs to these aquatic zones it would seem that the high water of the spring was able to prevent the shrubs from covering the entire area between the high water and low water marks by drowning them out, but was not able to prevent the marginal zone from occupying a space above the low water or ordinary level of the lake, since the species found there are at all stages indifferent to prolonged submergence and to considerable drying out as well. The shores of this lake, on the east and north sides, were high and steep and were covered with Norway and White Pine, which ran down nearly to the high water mark.

A Small Lake Near Badwater Lake.

This was about one-half mile south of Badwater lake, in the same depression, and was remarkable in several ways. Unlike Badwater lake, it had no outlet, and was surrounded by a well-developed peat bog, covered by a vigorous growth of Cassandra and other heaths with relatively few conifers except near the shoreward edge and in small groups near the water. The growth of shrubs was much wider on the western side of the lake than upon the eastern and came down into or very near, the water all about the lake. On the north and east sides

(Plate XXIV), was a narrow zone of the Slender Sedge, growing attached to the bottom, the water being about a foot deep beyond the thick edge of the turf, which the interlaced roots and stems formed. In a few cases the sedge was sending out long sub-aqueous rhizomes, or horizontal stems, a foot or more beyond the edge of this turf, into the clear water, but, in general, the new branches were growing outward and downward, diagonally over the edge of the turf, making, apparently, for the bottom. Growth in this direction would give a slower advance, but would make the resulting turf exceedingly tough and strong. In spots, outside of this sedge, were masses of Creeping Sedge and of Dulichium growing in the shallow water. In the deeper water were a few plants of the Yellow and White Pond Lilies and of Pondweeds, but these nowhere were abundant. On this part of the shore, fallen logs, which reached across the sedge into the water, were covered with masses of Cassandra and Andromeda on all parts above the water level. Above the sedge zone, and mingling with it on the shoreward margin, was a dense growth of Cassandra with some Andromeda. The Cassandra was very large here and, in places, was unaccompanied by other plants, not even moss growing under its dense shade.

Around the south and west shores where the shrub zone was broader, Andromeda and Cassandra were the marginal and advancing plants, the Slender Sedge appearing only occasionally and then as an intramarginal plant, 15 to 20 feet back from the water. (Plate XXV). Andromeda, along these shores, formed a dense fringe, reaching out into and over the water nearly four feet, the stems living and retaining their leaves as long as the leaves were above water, which was here more than 3 feet deep in most places, and more than 11 feet, where the mat was widest, with a soft bottom of vegetable ooze. The stems of Andromeda thus submerged did not send out roots into the deep water in most cases, as they did in shallower water, but were kept alive from the shore until they were submerged, or until the dead material beneath had accumulated in sufficient quantity to form a sort of substratum or soil for them. While this is going on, other plants take advantage of the support which the aerial parts of the stems afford and grow out upon them at and above the surface, binding the mass into a firmer structure. The plants thus growing on and around the advancing Andromeda and Cassandra here, were Sphagnum, Creeping Sedge, Slender Sedge, Prickly Sedge, White Beaked-rush, Small Cranberry, Buckbean,' Bulb-bearing Water Hemlock, Round Leaved Sundew, Pitcher Plant, Pale Laurel, and Marsh Cinquefoil, and all of these, but especially the sedges and shrubs, help in compacting and binding together the structure started by the Andromeda and Cassandra. A careful examination of this at its outer edge, showed it to be about a foot thick, firm and tough as though very old. A section through it, 6 inches from the margin, gave the following as its composition: A few inches of Sphagnum mixed with sedge root-stocks and leaves of various plants, then a layer of stems of Andromeda and other shrubs, very little decomposed, and mixed with the roots and rootstocks of sedges, below which was a closely interwoven mass of fine, branching shrub roots and the simpler ones of the sedges, which, together, make a very tough, compact substratum. The sedges had apparently bound the stems of the shrubs together by their roots and stems, and while this was being done the shrubs also sent out numerous finely branching roots which assisted in binding the lower parts of the structure together and added to its thickness. Below this turf, at the place where the section was made, the water seemed free from any sediment for some distance from the margin, but, nevertheless, the mat increased in thickness as one went shoreward. In shallow places, Andromeda was sending out long, slender, much-divided roots from the older nodes of the submerged stems, and it is probable that this occurs in deeper water as well, even where the roots cannot reach the bottom.

Patches of the dead stems of the Andromeda and Cassandra, beyond the present water margin and attached to the bottom in 2 or 3 feet of water, seemed to indicate that the water in the lake is higher than formerly, although it is possible that these masses may have been broken off from the margin in some way and have sunk by becoming waterlogged. The only aquatic plants seen near the border of the shrub mat, where the few plants of the Sweet-scented Water Lily growing very near to the shore in about 3 feet of water.

A small boggy lake on the east half of Sec. 7, T. 40 N., R. 30 W., in which open water covered about 15 acres, presented the following differences in detail from that last described: The shoreward border had a narrow zone of Spruce and Tamarack. There was a Sphagnum-Shrub zone of about 100 feet in width, in which the Pale Laurel, Cassandra and Andromeda were the most abundant plants, but the Buckbean, the Pitcher Plant, and the Tall and Virginia Cotton-grasses were also well distributed over the surface. Andromeda was by far the most active plant of the greater part of the marginal zone, showing distinctly as a pale green border to the open water or even forming islands 25 feet from the shore. The Cassandra formed occasional intrusions into the Andromeda zone, but was nowhere so abundant. In a small inlet on the margin there were patches of the Slender Sedge growing into the water, but not so vigorously as the Andromeda. The water along the margin of the advancing plants was from 2 to 3 feet deep, and a short distance from the shore there was a narrow, interrupted zone of the Yellow Pond Lily and the Common Floating Pondweed, into which, in some cases, the long stems of the Andromeda were pushing. In no part of the marginal zone of this lake was there any Sphagnum present with the advancing Heaths, the moss, in most cases, being several feet behind the advance of the shrubs.

Bog Near Twin Falls.

The final stages of such bogs as those above, were found in a small, steep-sided depression upon the section line between section 7 and section 12 of the next township west, a short distance from Twin Falls of Menominee river. Around the depression was a good second growth of White and Norway Pine growing down the sides nearly to the level of the bog, which covered an area of a few acres only, and had no open water upon it. In the middle of the bog, however, was an irregularly elliptical area, lower than the general surface and much wetter, which probably represented the part of the water surface last covered. Upon this wet portion the principal plants were low-growing specimens of Andromeda, with relatively few of Cassandra and Pitcher Plant, Virginia Cotton-grass, a slender species of Sedge and a small amount of Sphagnum. In the zone which extended shoreward of this, a hundred feet wide, or more, Sphagnum was very abundant, Cassandra covered most of the surface, reaching a height of 2½ feet, while in the center it was but a foot high. In this zone there were old stumps of trees, while Black Spruce, Tamarack and young Norway and White Pines were scattered over its surface. Labrador Tea was present only around the shoreward margin of this bog, forming a well-marked zone, which reached, at its upper limit, a height of 3 feet above the water level. Cassandra and the Pale Laurel also grew in this zone, and were here associated with the Canada, the Common and the Low Black Blueberries, the Twin-flower, Bunch-berry, Barren Strawberry, Wintergreen, Trailing Arbutus, Sweet-fern, Common Brake, and Clintonia, all plants of the high ground associations in this locality, and abounding on the wooded slopes. Sphagnum was found in this zone growing 2 feet above the water level in the bog. No attempt was made in this tension, or meeting, zone between the bog and upland societies, to find the level of the water in the mineral soil, but it was doubtless not far from the surface. Still, the drainage was sufficient so that in the upper part of the zone there was but a slight accumulation of humus, and the plants were all growing in nearly pure sand. The Common Alder grew up the slopes about this bog to a height of about 10 feet above the water level.

This bog gave additional evidence of the step-like advances which plants make over the surface of the water, in the well-marked zonation about the central depression. Apparently the shoreward border of the depression was for a long time the limit of open water, until the bottom was built up nearly to the surface, and then, in a dry period, the closing-in was accomplished and it is now only a matter of a short time when the surface will be of uniform height above the water level, as in a few years, Sphagnum and shrubs will cover the surface of the depression and fill it up, if the usual order of succession of plants goes on in ordinary course.

Lakes Near Sagola.

Of quite a different type from those just described, was a small lake a few miles south of Sagola in T. 42 N., R. 30 W. The lake was in a slight depression in a sand plain and had been surrounded by a Tamarack-Spruce-Cedar swamp, but the trees had suffered severely from fires, the surface of the swamp had been lowered from the same cause, and there were extensive tracts of Cat-tail growing under the dead trees and in depressions. The water in the lake was shallow, and had a good marginal zone of the Yellow Pond Lily and tracts of the same species scattered over the surface. Bordering the open water, was a zone of Sedge and Sweet Gale, extending to below the present water level, and shoreward of this was a zone of Cassandra and other heaths with Sphagnum in abundance, and still nearer the high ground was the Conifer zone. The Sweet Gale was here apparently the most active species in pushing out from the shore, as it was present along much of the margin, lakeward of other plants, and grew luxuriantly in the shallow water. This shrub grows so tall and is so dense of foliage that few other species follow it closely, so it does not build as firm a structure as other species do. From the depth of the water in which this plant was growing in places, there had probably been a rather recent rise of water in this lake.

A small lake, a quarter of a mile or so north of the one just described, and upon the east side of the road, was quite dissimilar in the plant associations which bordered it, although apparently no deeper. In this there were a few plants of the Yellow Pond Lily, much scattered. There was a very narrow zone of Andromeda with Cassandra, the Slender and other Sedges and quantities of the Marsh Shield-fern mixed with the shrubs. Growing up close to the marginal zone, was an open growth of Black Spruce, Cedar and Tamarack, associated with which were Andromeda, Buckbean, Marsh Shield-fern, Cassandra, the Small Cranberry, Marsh Cinquefoil, Cat-tail, Pitcher Plant, Marsh Bell-flower, Common Alder, Joe-Pye Weed, Wool-grass, Myrtle-leaved Willow, Three-leaved Solomon's Seal, and the Tall White Bog Orchis.

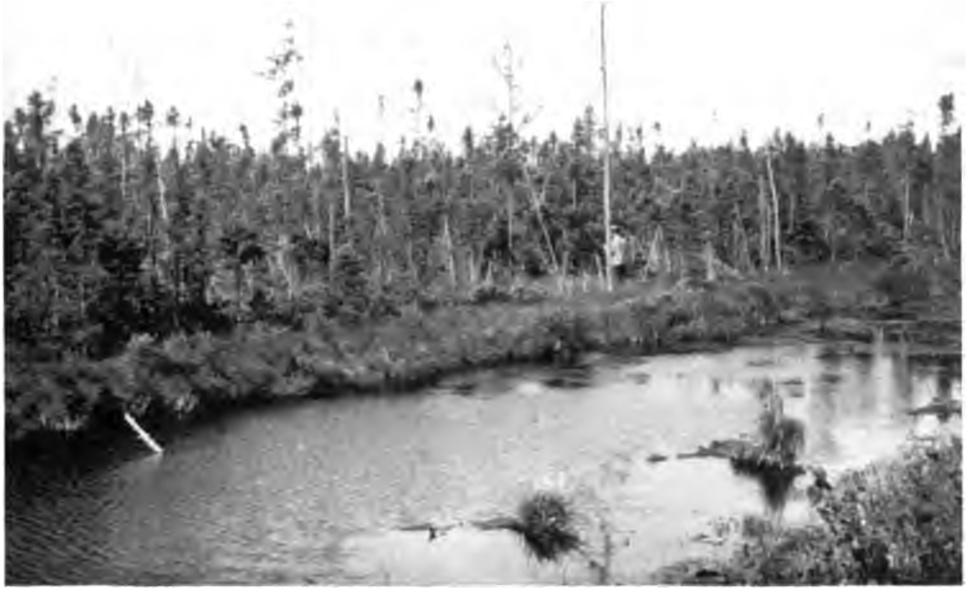
There were no indications here of any recent advance of the marginal zone lakeward, as the trees growing nearly to the water's edge were of good size and were many years old; the narrow zone of Andromeda about and in the edge of the water was thrifty, but was not making much growth into the water, and this may account for the lack of width, but there was no apparent reason for the slow progress lakeward, although a more careful study might reveal one.

Bogs and Lakes Near Crystal Falls.

The region about Crystal Falls, especially to the east and northeast, has many extensive swampy and boggy tracts which are covered by peat to a greater or less depth. These were originally Tamarack-Spruce-Cedar swamps now burned or cut over, and many of them have small lakes with more or less of open marsh in them. In general, these deposits, as far as tested, were found to be shallow, only a few feet in depth, but near the middle of the more extensive ones they were often more than 12 feet deep and the peat was of good quality.

In a few examples studied, the plant societies were noted, all, however, showing the effects of fire at some rather recent period in their history.

A Mature Bog: An area 2 or 3 miles north of Crystal Falls was evidently burned over 10 or 15 years ago, at which time the large Spruces and Tamaracks upon it had been killed, but since then a good growth of young trees of the same species has started. The surface was uniformly covered with a dense growth of Sphagnum associated with shrubs, of which the Labrador Tea and Cassandra were the abundant species, with a very little Andromeda, Pale Laurel and Small Cranberry growing with them. The water level was about 2 feet below the surface of the Sphagnum. Of herbaceous plants the Few-seeded Sedge and the Few-flowered Sedge were the most frequent types, but the Sheathed Cotton-grass, Pitcher Plant and Three-leaved Solomon's Seal were somewhat common. The Pitcher Plants were buried deep in Sphagnum, generally only the mouths of the openings in the tubular leaves showing, and as these plants were thriving, an apparent secondary use for the peculiar tubular structure of the leaves is suggested, viz.: that it gives exposure to the light when the leaves otherwise would



Old growth of stunted Black Spruce at Balsam, Iron County. The few Tamaracks are somewhat taller and show more open tops. The open water in the foreground is a ditch cut by the railroad, along which the overhanging Cassandra may be seen.

cease functioning, or nearly so, from being overgrown by the Sphagnum. As it is, the expanded lip of the leaf, which is not covered, and the interior of the tube give opportunity for the light to reach relatively large green surfaces, so that photosynthesis is able to go on without difficulty. It is even possible that the water held in the cavity of the leaf aids in diffusing and refracting the light so that it reaches all parts of the interior of the "pitcher."

This bog represents the general character of the mature phases of bog associations in the region. Of the immature phases, where there were lakes with marshes and bogs about them, a number were seen and a few interesting localities were studied.

Camp Lake, a Partly Filled Lake: Among these, Camp Lake, situated on sections 27 and 34, T. 44 N., R. 33 W., was visited, and found to have a wet sedge marsh around it, but next to the water was a narrower zone of Cassandra and Andromeda, which, as usual in cases where this occurred, was pushing out over and into the water. The Cassandra stems were extended horizontally more than 3 feet, and those of the Andromeda often 4 or 5 feet, into water at least 3 feet deep.

Under the margin of the advancing shrubs began a well-developed zone of Yellow Pond Lily, which was 50 or more feet broad, and beyond this was an aquatic northern form of Bur-reed growing in the deeper water, and forming a well-marked zone, lakeward of the Pond Lily zone.

Associated with the shrubs were the Slender Sedge, Marsh Cinquefoil, Pitcher Plant, Sphagnum, Marsh St. John's-wort, and the Round-leaved Sundew. The Sphagnum was growing upon the established turf a foot above the water level, and did not extend out into the water among the advancing shrubs. In the sedge zone were patches of Cassandra, extending shoreward nearly to the bank, and in many cases the remains of shrubs, charred by fire, showed that that destructive agent had recently modified conditions in this area. The most common plant of the sedge zone was the Bottle Sedge, but with it were the Slender and Mud Sedges, the Blue Flag, Wild Calla, Marsh Cinquefoil, and Sphagnum and Hypnum mosses below them in the wetter places. The conspicuous plant of this association was, however, the Bottle Sedge, which grew very tall and, with its yellowish foliage and large fruiting spikes, made a striking appearance.

Shoreward of the sedge zone was a well-defined zone of Blue-Joint Grass, several feet wide, which was above the water level and which landward merged abruptly into the plant society of the burned over pine lands.

The unusual relation of the sedge and shrub zones here, and the fact that the shrub zone is higher than the surface of the sedge zone, may indicate that a severe fire, at a time when the water in the lake was low, destroyed much of the peat which had accumulated, leaving only a narrow border near the water in which the peat was too wet to burn; this was the nucleus of the present growth of shrubs at the margin of the lake, and in the depression behind it, the sedges have since established themselves and the water level has risen until a wet marsh is the result. The fact that the lake lies in a region which has been cleared of pine, and that evidences of fire were seen below the water level at the time when the lake was visited, makes the hypothesis advanced seem the more reasonable.

Spring Bog Near Camp Lake: Camp lake is a partly filled depression in an elevated portion of a dissected gravel plain and has no outlet above the surface, but about one-eighth of a mile to the west is a steep slope, at the bottom of which, 50 feet below the level of the lake, is a large spring-bog, covered around the margin by an old growth of Cedar, Tamarack and Spruce, with an open bog and small lake in the middle. This is fed by a great number of powerful springs, and is apparently one of the outlets for the water of the lake, although the porous nature of much of the higher land in the vicinity would not preclude the supposition that these are ordinary seepage springs, if it were not for the large number which are to be found over the bottom of the depression and the proximity of the lake without other outlet. The pool formed by the union of the waters of these springs was of considerable size, surrounded by a floating or quaking bog, bordered by stools of the Bristly Sedge, together with quantities of the Marsh Shield-fern and the Sweet Gale. The latter bordered the shallow water of the pond, in which were some plants of the Yellow Pond Lily and many small islands of Sweet Gale. Shoreward of the Sedge-Sweet Gale zone, was a broader one, covered by Sphagnum to a depth of a few inches, where the water level was 4 inches below the surface; and growing in the soil thus formed were Buckbean, Small Cranberry, short, small plants of Andromeda and Cassandra, Cotton-grass, Pitcher-Plant, Marsh Cinquefoil, Mud Sedge, Marsh Shield-fern and several Orchids.

This marsh gave place, landward, to a slightly dryer one, with deeper Sphagnum and larger shrubs in which were clumps and individual trees of young Tamarack. The herbaceous plants here were several species of sedges, among which Magellan's, the Lesser Panicled and the little Prickly Sedges, were the most noticeable, Buckbean, Pitcher Plant, and Orchids, here very abundant, of the three species, the Tall White Bog Orchis, the Tall Leafy Green Orchis and Ladies' Tresses. In parts of this area were beds of Andromeda nearly buried in Sphagnum.

Still nearer the high ground was the mature Conifer zone, rather open on the pondward side, but dense farther in shore. In this, the Sphagnum had built up mounds, in places from 2 to 3 feet high. At the latter height, however, the Hair-cap Moss was almost invariably on top, and where it was not, the Reindeer Lichen replaced it. On the tops of these mounds, growing among the mosses, were Labrador Tea, Bunch-berry, Creeping Snowberry, Twin-flower, Goldthread, Marsh White Violet, Fringed Polygala, Mountain Maple, young Tamarack, Common Horsetail, Goose grass, Clintonia, Red Raspberry, Three-leaved Solomon's Seal, and Small Bishop's-cap.

Between the hummocks built up by the Sphagnum around shrubs and tree roots, often in the water, were found Wild Calla, Marsh Marigold, Swamp Saxifrage, Pitcher Plant, Round-leaved Sundew, Buckbean, Small Cranberry and Marsh Shield-fern. In parts of this zone, where it was not deeply shaded, Sweet Gale grew with Labrador Tea and Cassandra upon the stools about the roots of trees, 2 to 3 feet above the water level, where Sphagnum was giving place to Reindeer Lichen, thus growing at the greatest distance of any of the marginal shrubs above the water level, as well as below it.

The water in the springs was cold and clear with an irony taste, but the outlets were often clogged with dense masses of Algae, through which the water bubbled up and flowed away in small streams. Around these outlets were sometimes beds of Hypnum moss, with which was usually growing quantities of Smaller Bur-Marigold. The spring outlet-streams were usually lost in the marsh, before reaching the pond, but a few of the stronger ones persisted until they reached it; the surface of the bog sloped slightly from the older timber zone to the pond and apparently had been built up as the result of peat development following the constant outflow of water over the surface, which created conditions favorable to its development. This and a similar bog near Runkle Lake, about a mile and a quarter east of Crystal Falls were the only spring-formed bogs visited. The Runkle Lake bog was also caused by springs which were the only outlet of the lake, but was more nearly of the ordinary type of mature Tamarack-Spruce-Cedar association, such as has been frequently described.

Bogs Near Amasa.

A River-Flooded Lake: The point farthest north which was reached in this region was the town of Amasa, T. 44 N., R. 33 W., where on section 5, a small lake near Little Hemlock river, was examined.

The marginal zone here was made up entirely of Sweet Gale, which was advancing over the water, and the Tussock Sedge, shoreward, of which was a continuous zone of Cat-tail, Sweet Gale and Common Alder, sometimes mixed and sometimes in dense patches of a single species. Still nearer the shore was a marsh in which the Tussock Sedge was the dominant plant and had built up tussocks to a height of more than two feet, with nearly dry ground between. Some Sweet Gale grew between the tussocks and upon them were thrifty plants of Cassandra and Blue-Joint Grass. The plants, beside the Sweet Gale, which were found growing with the Cat-tail, were Sphagnum, the Marsh, Willow-herb, Marsh Shield-fern, Marsh St. John's-wort and Marsh Cinquefoil. Under dense patches of Sweet Gale in this zone, there was some Sphagnum and a few small light colored plants of Marsh St. John's-wort and Touch-me-not. The water level in this zone was about 6 inches below the surface of the quaking turf-like structure upon which the plants were growing.

The shoreward marginal zone was made up chiefly of shrubs, of which the Sweet Gale was the most abundant, but the Common Alder, Buckthorn and Cassandra were common, while upon the tussocks of sedge were occasional plants of Labrador Tea. Between this zone and the high ground vegetation, there was formerly a zone of conifers, as charred stumps showed, but when visited no trees existed there. The lake was in a gravel plain and was formerly surrounded by a pine forest.

The close connection of this lake with the river suggests the probability of periodical flooding of the marginal zone, which in turn, may account for the mixed character of the associations of the various zones and the wide distribution of the Sweet Gale.

A Mature Bog: On section 6 of the same township, was a well preserved bog of the mature type, which was characteristic of the bogs of the vicinity. The surface was covered by a dense growth of Sphagnum, which was from 1 to 1½ feet deep, and the water level from 1½ to 2 feet below the surface of the growing moss. The trees were chiefly stunted Black Spruces, which were mixed with a few Tamaracks. The shrubs were Cassandra, the dominant species, Andromeda and Pale Laurel, common, and Labrador Tea rather frequent, but growing best on the tops of the Sphagnum knolls and on stumps and roots of trees, and it was the only shrubby heath on the dryer ground of the margin, except the Blueberries which were here associated with it. The herbs growing in the Sphagnum were Pitcher Plant, Three-leaved Solomon's Seal, Sheathed and Virginia Cotton-grass, Three-seeded Sedge, Creeping Snowberry; Mountain Ash was abundant near the shoreward margin with the Labrador Tea. The peat here was full of roots and fallen logs and about 10 feet deep where tested.

Spruce Bog at Balsam.

At Balsam station (section 13, T. 44 N., R. 33 W.) the junction of the Amasa branch of the C. & N. W. R. R. and the Superior division of the C. M. & St. P. R. R., was a fine example of a Spruce bog. (Plate XXVI.) The Spruce was much stunted and rather sparsely distributed over the surface, with a few small Tamaracks mixed with it. The surface of the bog was covered with a Sphagnum-Heath association with Cassandra the dominant plant, and Andromeda and Pitcher Plant abundant.

Over much of the surface the water was less than a foot down, but in places where the Spruces were grouped together the Sphagnum had grown up around them to a height of more than 2 feet above water and in such places, Labrador Tea and Canada Blueberry were frequent on the tops of the hummocks. On some of these hummocks the Hair-Cap moss had established itself and frequently the Reindeer Lichen as well. Besides the plants mentioned, the general bog association included the Small Cranberry, the Virginia Cotton-grass, Three-leaved Solomon's Seal, and Few-flowered Sedge. The Spruces were many of them infested by the parasite, the Small Mistletoe, and there were hundreds of dead Spruces which seemed to have been killed by this pest, while many of the living ones were distorted by its attacks, showing the characteristic "witches' brooms," due to abnormal branching. In the ditches beside the railroads were found Cassandra and Andromeda frequently nearly filling the ditch, while in some places Sphagnum was growing abundantly as an aquatic, one of the very few observations of this character made during the entire trip and apparently a rare occurrence, even in similar situations. Where holes which reach below the water level are cut in the peat upon which Sphagnum is growing, as in the case of these ditches, the moss will sometimes establish itself in the water. That it does not always do so, or even usually, may be due to the fact that the species which can live in the water are not present when the holes are cut.

In places where fire had burned off the surface layers of moss and shrubs so that the water level was near the surface, the Few-flowered Sedge and Pitcher Plant were prominent, but the other plants of the Sphagnum-Heath association were usually present with them and apparently would soon surpass them.

This body of peat, while not of great extent, is near others and most favorably situated for exploitation in connection with the iron mines at Amasa and Crystal Falls. It is, however, rather shallow, averaging about 6 feet in depth where tested, and was only 7 feet, near the middle. The peat was rather light colored and not well decomposed.

In several places, "islands" rising above the general surface were noted. Some of these were burned off and showed a formation of mineral soil, with 2 or 3 feet of peat above the water level. On such islands Labrador Tea grew with great luxuriance. The railroad grades were, in part, covered by grasses, but in places the bog heaths, especially Cassandra, had established themselves upon them, and the Canada Blueberry was often a dominant plant near the top of the 4-foot gravel embankment.

Sand Plain Lakes and Bogs South of Crystal Falls.

In the extensive sand plain, south of Crystal Falls are a large number of depressions, some of which have bogs in the mature stages, while others have lakes with scarcely a trace of filling. Some of these unfilled lakes are shallow, while some of the partly filled ones are very deep off the edge of the boggy margin, so that it seems apparent that depth does not control the rate of filling, although if other things were equal this would be the case. The following examples from this sand plain region illustrate this interesting point, as well as show the conditions of peat formation existing there.

In the vicinity of Clara Lake, T. 42 N., R. 32 W., the open plain is rolling in character with occasionally a rock hill a hundred or more feet above the general surface. The prevailing flora is that of burned over pine lands, and the chief species of pines here are the Jack and Norway, while Scarlet Oak, Poplars, Sweet-fern, the low Blueberries and various dry ground grasses and sedges constitute the greater part of the rest of the flora.

A Rejuvenated Sedge Bog Near Clara Lake: In a small depression, a mile or so south of Clara Lake, the water was about 3 feet deep when visited, and in it was a dense mass of Slender Sedge covering the deepest part of the pond. Surrounding this was a well marked zone of Bottle Sedge, growing in water 1 and 1½ feet deep, shoreward of which was a zone of Tall Manna-grass and Blue Flag. From the water's edge up to about 2 feet above it, was a zone of Willows and Meadow-Sweet, and above this, Blue-Joint Grass, Sweet-fern and Tall Blackberry formed a well marked zone around the depression. This was an unusual combination, and was probably the result of rather recent disturbance of plant relations by fires which destroyed the older association, and the ground was then occupied by the plants nearest at hand. There was no indication that the bottom of this depression, shallow as it was, had ever been filled with peat.

Two Shallow Lakes in the Sand Plain: In a shallow lake on sections 21 and 22 of the same township, was a more usual association, but one not frequently observed in the region: the Yellow Pond Lily formed a wide zone, in which were some Pondweeds and White Pond Lily plants. The shoreward margin of this, was marked by a narrow zone in which the Lake Bulrush was the dominant plant, but growing with it, the Creeping Spike-rush was abundant in places, as well as the Cat-tail. Near the water's edge, but growing in it, were small areas of Dulichium. At the water's edge or a little below it was a well marked zone of chiefly Sweet Gale, but in places the Slender Sedge and Tussock Sedge replaced it. This zone of Sweet Gale extended up to about 3 feet above the level of the water, where it was replaced by an association in which the Common Alder was the most notable plant. In the Sedge areas were Marsh Cinquefoil, Marsh St. John's-wort, Marsh Bell-flower, Wild Mint, Great Water Dock and in the higher parts of such places were some Sphagnum. Cassandra formed a slight admixture with the Sweet Gale in a few spots. This lake, with abundant aquatic vegetation, was characterized by the narrow zone of marginal plants, which had made no progress away from the shore, so that there was no border of peat.

Another apparently very shallow lake was visited 2 or 3 miles southwest of the last one, which, while it was scarcely more advanced in the filling process than the one above described, was of sufficiently different character to warrant brief description. It is located in a region of steep, high, sand and gravel ridges, which were formerly covered by a dense forest of Norway Pine, now replaced by shrubs and Poplars with a few small pines. In the lake were scattered plants of the Yellow Pond Lily, but nothing approaching a zonal development. The margin of the pond had a border of Cassandra and Andromeda from a few feet to a few yards wide, both species reaching out into and over the water, the latter rather more frequently than the former. In this border were some Spruces and Tamaracks in the part nearest the shore and Sphagnum, with its surface 1 to 2 feet above the water level, was constant in all the lakeward margin of this zone, and in many cases was growing out beyond the limits of the shrubs upon fallen logs, but was nowhere seen in the water in such places. In this Sphagnum-shrub bordering zone were the Buckbean, Pitcher Plant, and Round Leaved Sundew near the water level, and back among the trees on higher places with Cassandra were the Small Cranberry, Labrador Tea, Creeping Snowberry and Choke-berry, here noted for the first time in a bog in this region. These plants ascended the slope to a height of about 3 feet above the water and were competing with the Canada and Low Blueberries, and Common Brake for the ground. In this tension zone were also found the Mountain Holly, and the White and Norway Pines.

Deep Lakes Near Stager: South and west of Stager, were two remarkably deep lakes of the tarn type separated by a high, narrow, steep-sided gravel ridge, on which the wagon road runs. The slopes of this ridge were continuous with those of the bottom of the western lake, which was very clear and deep, and apparently also with those of the eastern one in which the water was also very deep. The western lake had only a very narrow marginal zone of Cedar and accompanying plants, and in one place a small area of Slender Sedge. These plants had not begun to advance over the water at any place and the steeply sloping bottom could be seen to a depth of 25 or 30 feet below the surface, and water logged trees and similar débris distinctly seen lying on the slopes.

The bank upon the eastern side of the road was even steeper than that on the western, nearly perpendicular in one place, for several feet, and apparently ran without a change of slope into the lake, which was somewhat larger than the other. About this lake, however, there was a well developed heath bog, several hundred feet wide, all around the open water, in which Cassandra and Andromeda were the dominant plants, except for several rods of the shoreward margin where there was a well developed Tamarack-Black Spruce zone.

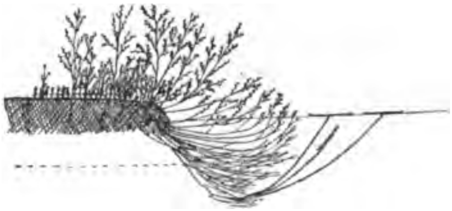


FIG. 13. Diagram showing way in which Andromeda and Cassandra built out a mat over the water in a lake near Stager.

The Andromeda and Cassandra were growing out from the edge of the tough mat, somewhat as shown in Figure 13, over and into the water to a distance of 3 or 4 feet, where the water was so deep that the bottom was not visible, although the water was sufficiently clear to allow the light to penetrate it for more than 10 feet. There were large masses of submerged branches and twigs of the shrubs in the water below the living ones and apparently it was these which furnished the substratum upon which finally the shoots, sent out from the margin of the mat, took root, and gained sufficient stability to permit other plants to grow out upon them. Growing out from under the edge of the fringe of partly submerged shrubs, from an invisible base of attachment, which may have been the lower part of the mass of branches just described, were a few plants of Yellow Pond Lily, but nothing like a zone of this species was present. There were no plants of other species growing upon the partly submerged shrubs, except a few plants of the Small Cranberry, but where the turf was established, Sphagnum was present, and with it the Small Cranberry was very abundant and associated with the Few Flowered Sedge, Pitcher Plant, Tall Cotton-grass, Pale Laurel, Three-leaved Solomon's Seal, Scheuchzeria and Buckbean. Cassandra, Pale Laurel and Labrador Tea were the chief shrubs of the conifer zone.

These two basins were the deepest small ones visited, and no cause was apparent why the larger one should be so far advanced toward filling, or at least toward being covered, while the smaller one, with identical structure and conditions should not have begun to fill, except that the proper plants had not become established about it. Neither was there any assignable cause why this deep lake should have so far advanced in developing into a bog while the much shallower ones described above, with the same plants about some of them, had made little or no progress in such development. In the case of the deep lakes just described there had been no severe fires about them in recent years, since there were mature living trees of several species about their borders.

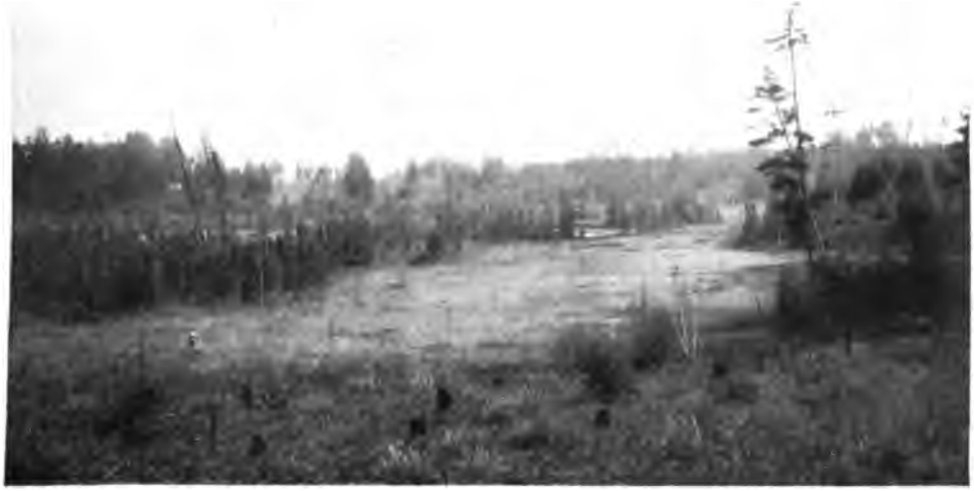
Mature Bogs Near Mary Lake: In the vicinity of Mary Lake, T. 42 N., R. 31 W., also in the gravel plain region, two mature bogs were visited. The first of these was a heath bog, highest in the middle, with dense growth of Cassandra and Andromeda on it, around which were either stretches of open water, or a broad zone of Slender Sedge and Bottle Sedge, with water a foot or more deep, while the landward margin from the water level up to 3 feet above it, had a zone of Cassandra again, here growing in sand with Meadow-sweet, Low Blueberry, Bearberry, Twin-flower and other plants, some of which are important members of the Norway Pine association of the surrounding barrens.

A short distance south of Mary Lake was a large depression in which was an extensive sedge marsh, the only one seen in the entire expedition, in which the Few-seeded Sedge was the dominant plant over so large an area. This was apparently a rejuvenated mature bog in which fire had swept away the plant association of the mature stages and at the same time lowered the surface of the peat to the water level; thus conditions favorable for the growth of the sedge were developed, and as the plant is frequent in mature bogs in the more open and moister places, where fire might not destroy it, it may have spread from these places as centers until it covered the whole area. This would be especially the case if there were, at the same time, increase in the rainfall sufficient to make the burned-over peat very wet.

Evidence of burning existed in this bog in the form of numerous charred tree stumps, with more or less exposed roots; these served as the nuclei of islands of Cassandra and Sphagnum. Towards the middle of the marsh the Cassandra became more generally spread over the surface, and here there were stunted Black Spruces and Tamaracks.

Around the Cassandra and other shrubs, and the trees, Sphagnum was usually found building up the surface a foot or two above the water level. This moss was also abundant in the shallow water of the Sedge marsh, rising but an inch or so above the surface, or at most only 6 inches. Aside from the Cassandra plants and groups of Andromeda, Dwarf Birch and the Myrtle-leaved Willow were the centers of Sphagnum islands.

Growing in the water with the Few-seeded Sedge were the Mud Sedge, the Slender Cotton-grass, Scheuchzeria, and Flat-leaved Bladderwort, while the Pitcher Plant and Small Cranberry were occasionally found upon the Sphagnum islands. An unusual association was found in places, in the wet, shoreward margin of this bog, where the Three-seeded and Little Prickly Sedges and Wool-grass formed groups of low hummocks. Still shoreward of this, above the water level and outside the bog, growing in the sand, was a zone of Alder, Dwarf Birch, Pale Laurel, Labrador Tea, Choke Berry and Mountain Holly. These plants were all thrifty and were noticeably larger and stronger than those growing in the bog and grew as much as a hundred feet from its margin. The Labrador Tea was the most abundant of the heath plants here, and in many places covered the ground for a distance of from 50 to 100 feet from the edge of the bog and successfully held it, in competition with the usual sand plain vegetation, here represented by Norway and Jack Pines, Beaked Hazel-nut, Tall Blackberry, Prairie Willow,



Spruce—Shrub—Sedge-bog near Lake Mary. The dense growth of Black Spruce is shown on the left, the small remnant of open water to the right of the center. The hills around have White and Norway Pine, or stump land, with low shrubs and herbs.

Sweet-fern, Low and Canada Blueberries, Trailing Arbutus, Bunchberry, Common Brake, Clintonia, Cow Wheat and Hair-cap Moss.

The occurrence of Labrador Tea in this association of well known dry ground plants, is exceedingly suggestive as to its power to resist drought; in the observations made up to this time it had been noted that this plant was practically always found in the dryest parts of the bogs in which it grew, but this was the first observation made, and amply confirmed by later ones, where it was a member in good standing of the drought-resisting or xerophytic association of the sand plains, away from true bog conditions.

The climax of this series of sand-plain bogs was about a mile west of Mary Lake, in a large depression in a rolling part of the sand-plain. (Plate XXXII.)

In one place, to the south of the center, was a small pond of open water, very shallow with a bottom of finely divided peat in which were growing the White and Yellow Pond Lilies and the Water Shield. This pond presented a peculiar problem, in the fact that the borders of it seemed to have been broken up rather recently, possibly by the wallowing of bears or trampling of deer so that its area had increased. The margin was irregular and in places in the water there were masses of dead shrubs with tops standing above the water, not as islands, but as if attached to irregular fragments of larger masses or the submerged remains of the former shore. Around the present margin was a zone of bare peat several feet wide, a very unusual condition, extending nearly around the entire pond. Back from this, was an association very rich in species for this zone, in which Sphagnum was very abundant and covered the surface. Growing in it were Pitcher Plant, Slender and Virginia Cotton-grasses, Mud Sedge, Scheuchzeria, White Beaked-rush, Few-seeded Sedge, Small Cranberry and small plants of Cassandra and Andromeda. This was surrounded by almost pure Black Spruce growth, the trees stunted and scattered, in which Sphagnum had raised the surface in mounds, in places nearly 3 feet above the water level. Here the shrubs and other plants were in about the association usually found in such bogs, but in much of the open space between the trees, the Few-seeded Sedge was rather more abundant than was usual in such places. Towards the shore, the Sphagnum was not as deep, the water was nearer the surface and the Spruces had been killed by fires. In this zone the Few-seeded Sedge and Cassandra were the chief plants over considerable areas, in the wetter places the sedge, and in dryer ones the shrub predominating. The amount of peat in this bog was large, as the depth was over 10 feet in most of the area, but it was very wet, so that in many places near the margin the mass could be shaken without much effort. In dryer times it is probable that there would be less percent of water in the peat, as the water level sank, but it is doubtful if such a deposit could be utilized under present conditions on account of the cost of preparing it for fuel.

Bog Near Iron River.

The only bog visited in the vicinity of Iron River, was found about a small lake 2 miles south of the town. The lake, or pond, was very shallow, showing bare flats in many places, with a peaty bottom and was full of small islands, covered by Broad-leaved Arrow-head, Bristly Sedge, and Creeping Spike-rush. The surface of the water was covered in most places by Pondweeds and Yellow Pond Lily, with considerable of the Arrow-head in shallower places. The marginal zone was from 3 to 5, up to 10 feet wide, in places examined, was easily shaken, and was occupied almost exclusively by sedges, of which the Slender Sedge and the Creeping Spike-rush were the ones making most rapid advance over the mud bottom. The Tussock, Bristly, River-bank, and Porcupine Sedges, were all more or less engaged in forming tussocks along the margin and in this way were aiding in extending the zone. In a few places the Lake Bulrush was established near the shore, but covered no large areas. Dulichium, Buckbean and Marsh Cinquefoil, and in a few places, Sphagnum were also forming small patches here and there in this zone, but Sphagnum was quite rare, and the other plants unimportant. Shoreward of this zone was a much broader one of Sphagnum, with which were growing Tamarack, Common Alder, Cassandra, Pale Laurel, Marsh Cinquefoil, Small Cranberry, Pitcher Plant, Blue Flag and several sedges. Still farther shoreward, was a dense growth of Cassandra, and a zone of Sedges, Andromeda, Pale Laurel and Meadow-sweet growing with thin Sphagnum ground-cover. This portion was practically all above water level, so that the peat was firm and dry, even in paths a foot or more below the general level of the moss. The surface sloped gently upward to higher ground and grew more and more dry, but the heaths persisted into a zone where the Hair-cap Moss replaced the Sphagnum almost entirely. In a part of this, the Pale Laurel was exceptionally abundant and vigorous, while Cassandra and Andromeda also were growing better than usual. With these shrubs were the Marsh Cinquefoil, Sedges, Blue Flag, and some other species. At the top of the slope was a zone of Blue-Joint Grass and still higher a thin growth of Poplars. Fire had swept over a part of this bog, but so long ago that most of the plants had nearly reestablished themselves, although clearing had undoubtedly increased the importance of the shrub and herb societies, above the marginal zone. The fact that the surface of the bog sloped, and that the water was so shallow, suggested a recent lowering of the water by ditching, but no time was available to find out whether this had been done.

Mature Peat Bog North of Bessemer.

During a two days' stay at Bessemer, a trip was made to a large peat bog on Eight Mile Creek, north of the city. This was one of the most interesting bogs visited, in spite of the monotony of the conditions, for it had never been disturbed by fire or by man. The swamp or bog was covered by a growth of Black Spruce with some Tamaracks along the borders and occasionally in other places. The Spruce trees were of small size, slow-growing, as shown by the distance between the whorls of branches and were covered with lichens. The ground was usually covered with Sphagnum and shrubs but in many places the shade of the trees or shrubs was so dense that apparently the moss was unable to grow. Along the creek Cassandra grew very luxuriantly, reaching a height of about 5 feet and forming such a dense cover that nothing was growing under it, although there was a sparse growth of old Tamaracks overtopping it. At a distance of from 8 to 15 rods from the stream the Cassandra was less dense, and Sphagnum and Black Spruce became the most noticeable plants. The Spruces were irregularly grouped with larger or smaller open spaces between them, thus forming a somewhat open stand. In the denser shade of the clumps there were practically no plants with the Sphagnum, when this was found in such places, except the Creeping Snowberry, which was frequently found alone, covering the ground with its delicate tracery. The more open places between the denser clumps of Spruce, had an association in which, besides Cassandra, were Labrador Tea, Canada Blueberry, Pale Laurel, and, rarely Andromeda; Small Cranberry and Creeping Snowberry often formed dense mats over the Sphagnum. The Labrador Tea and Laurel had very broad and large leaves in this locality, probably an adaption to the reduced light, since plants in more open places, had much smaller, narrow ones. The herbaceous plants noted here were Stemless Ladies' Slipper, Indian Pipe, Wintergreen, Three-leaved Solomon's Seal, Pitcher Plant, Few-flowered and Few-seeded Sedges. This association occurred with slight variations as to the number of individuals of the given species, according to the depth of the Sphagnum, or the amount of shade developed by the trees, over wide areas in this bog, in fact in every part visited.

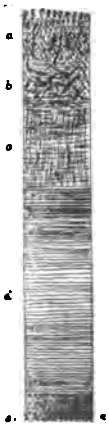


FIG. 14. Section of Bog north of Bessemer.

a. Sphagnum and shrub remains.
b. Sedge and shrub remains, poorly decomposed.
c. Sedge roots and fine material.
d. Structureless peat.
e. Clay and sand.

The peat was tested in several places; the first section gave the following: Sphagnum 1 foot; coarse, poorly decomposed peat with roots of trees and shrubs, 1 foot; below this the peat was finer grained and compact, with an abundance of sedge roots and fragments of rootstocks for 2 feet; at 9 feet fine clay 3 inches, below which were sand and gravel. Water at 1 foot from the surface. (Fig. 14.)

Another test showed the Sphagnum to be from 8 to 19 inches deep, abruptly changing to compact, rather coarse, dark-brown peat, with abundant sedge remains, to a depth of 6 feet, then sand. The water level averaged 1 foot below the surface here. At a third station, a long distance from the second, the Sphagnum was about a foot thick in the lower places and nearly 2 feet in the higher, where it was growing about shrubs, etc., i. e., variations of the surface were largely due to the variation in depth of Sphagnum. Below this the peat was rather coarse and dark colored, to a depth of 9 feet, with 5 inches of fine clay at the bottom and then sand. The water level here was about as it was in the other holes.

It is evident from these borings, and numerous other tests here, that Sphagnum is only a superficial plant, which is of recent introduction upon the surface of the bog, for Sphagnum remains do not appear in the more compact peat below the bottom of the moss. The peat formed by Sphagnum is so characteristic, so different in texture and color from that formed by any other plant, that it is not to be mistaken, when once it has been examined, for anything else, and peat with any considerable amount of the plant present, is very readily recognizable. The tests made point to the fact that this deposit was built up largely by other plants than Sphagnum, and that for a considerable time before the Sphagnum established itself, the sedges were abundant and were efficient in building up the surface of the bog. What the plants were which built up the lower parts of the deposit, was not determined, but there was no indication that they were sphagnum. In this deposit of peat, the plants seemed to have followed the same succession and developed the same association as the climax, as those which were examined further south, and in most respects the flora would be identical with that in spruce swamps throughout the region studied, but it would be very rare in more southern parts of the state to find such an extensive development of peat in so shallow a depression, if any were formed in it at all.

Lakes and Bogs in the Keweenaw Peninsula.

For the sake of comparison, and to determine, if possible, whether any different factors or plants entered into the formation of peat bogs in the northern part of the Northern Peninsula, from those found in the southern part, a brief reconnaissance was made in the region about Houghton, during the first week in September. A trip was made to the Winona mine near which there were several small lakes, partly filled, and some bogs representing completely filled ones.

Bog Near Winona Mine: The first locality visited was a small bog in a heavily wooded country, the chief high-ground trees being Yellow Birch and Sugar Maple. The bog was in section 32, T. 52 N., R. 36 W., was elliptical in shape, with a distinct zonal arrangement of the plants about it and had in the center an open marsh in which sedges and shrubby heaths were about equally abundant. This area of open marsh was about 250 feet long by 150 feet wide. The water level was about 15 inches below the surface of the higher parts of the mat of vegetation, and a foot or less in the lower ones. Sphagnum covered the surface and was the cause of its elevation above the water level, and with it, the following plants were found: Cassandra, Andromeda, Pale Laurel, all rather small and low, the Andromeda more common here than in other zones, the Small Cranberry, Pitcher Plant, the Few-seeded, Mud, and Few-flowered Sedges and Cotton-grass. Shoreward of this area was a zone of Black Spruce and Tamarack, the former dominant, with the following associates: Sphagnum, Labrador Tea, Cassandra, Pale Laurel, Andromeda, and on elevations of the surface, with Labrador Tea, the Canada Blueberry. The herbs here noted were Magellan's Sedge, the Sheathed and Virginia Cotton-grasses, and Pitcher Plant. This zone gives place in turn, to one in which the Spruce is wanting, except very young plants, and the Tamaracks are very large. With these were young Red Maples, White Pines and Yellow Birches, and besides most of the shrubs and herbs of the other zones, Creeping Snowberry, Three-leaved Solomon's Seal, Three-seeded Sedge and Cinnamon Fern were found, the last, the most abundant herbaceous species and forming a striking zone by itself on the shoreward edge of the old Tamarack association. Between the Fern zone and the high ground was a slight depression, without standing water, a marginal fosse or ditch, in which grew the Blue Flag, Wild Calla, Three-seeded Sedge, and Sphagnum.

In the open part of the bog the water was about a foot below the surface of the growing Sphagnum, and at 1½ feet, shrub remains were few and the amount of Sedge and Cat-tail débris increased to a depth of 2 feet, when the peat became very watery, and was too liquid to gather samples from, to a depth of more than 10 feet.

In the Spruce zone, the water level was about 1 foot below the surface of the moss, and the turf was composed of shrub and moss débris to a short distance below the water level where the material changed abruptly to Sedge and Cat-tail rootstocks and leaves. Below this the peat remained fibrous, light colored, and very watery to a depth of more than 10 feet. The water level was nearly 2 feet from the surface in the old Tamarack zone and the surface was much dryer, especially around the bases of trees, and it was on these elevations that Labrador Tea and Canada Blueberry were growing most luxuriantly.

The outlet of this bog was a small, badly-clogged brook flowing through a peaty valley, and it seemed quite probable that, as the peat had accumulated in the valley, it had slowly checked the outflow from the basin and thus raised the level of the water in the basin and this in turn had tended to raise the surface of the bog by encouraging the growth of the peat-forming sedges and other plants. It was apparent from the study of sections that the Sphagnum had only recently, compared with the total age of the bog, established itself upon the surface of the deposit which had been covered by sedges and Cat-tail.

Lake Near Winona Mine: On section 33 of the same township was a small lake surrounded by steep banks covered by a Birch and Maple forest, except near the foot of the slopes where Hemlock, Balsam and Yellow Birch were the important trees. The lake is about twice as long as wide, and at the north end has a small bog, which was rather hastily studied. In the water along the margin of the bog were patches of Yellow Pond Lily and a Pondweed and in other places, the Submerged Burreed, a species of Arrow-head and the Greater Bladderwort were noted.

The chief plants along the water margin were Cassandra and Andromeda, which were generally advancing the turf by the growth of partly submerged branches reaching over and into the water. The plant which here was most closely following the shrubs was the Blue Flag, a very unusual marginal plant in the region which had been traversed up to this time, in fact it was rather rare in the bogs at all, except occasionally along the shoreward margin. Here, however, it made an abundant growth among the shrubs on the edge of the turf nearer the water than any other plant except the Small Cranberry, which was occasionally found growing over the water upon the shrubs.

Immediately shoreward of the Blue Flag zone was Sphagnum, which, however, was unequally distributed, being present in some places and absent in others, over most of the surface of this part of the bog. In the places where it was present, it often built the surface a foot or more above the water level, and growing with it were the Small and Large Cranberries, Scheuchzeria, Pitcher Plant, Mud and Few-flowered Sedges, the Slender Cotton-grass and Dulichium. The Pale Laurel, Marsh Cinquefoil, Cassandra, Andromeda, and Buckbean were present in the open places where the Sphagnum was wanting, and, where water was covering the surface, or very near it, the Horned Bladderwort and White Beaked-rush were often abundant.

An interesting object of study was afforded here by the plants which had established themselves upon a dead tree which had fallen into the water, extending from the shore, across a narrow marshy sedge-border, out about 30 feet before the end was covered by the water. Andromeda was farthest from the shore and the nearest plant to water level, which was from 4 to 6 inches below the part of the log upon which it was growing. Sphagnum and Cassandra were nearer shore, and a fine specimen of the Pitcher Plant was next shoreward, and quite close to the shore, where the top of the log was a foot above the surface of the water were a young Yellow Birch and three thrifty specimens of young White Pine, at least 10 years old.

Back shoreward from the open Shrub Sphagnum association was a Conifer zone, the Black Spruce-Tamarack association, here not well developed, except as to shrubs, which were the same as those mentioned above. Shoreward of this, was a broad marginal ditch, with water a foot deep, and in this, Slender Sedge was growing abundantly, while between it and the Conifer zone was a good growth of Blue-Joint Grass and Alder, making a narrow and incomplete zone. On the sides of the lake where the bog was narrow or wanting, were the same shrubs as on the bog, but frequently also, patches of Slender and Prickly Sedges and the Creeping Spike-rush, growing in the shallow water. In the water in places, the peculiar little Pipe-wort was growing, but not in sufficient quantity to make it a factor in the filling of the lake.

As will be seen by comparing these bogs with others described, they present no marked peculiarities, the chief ones being the presence of the Cinnamon Fern in the first, and of the Blue Flag in the zone of advancing plants, in the second, but these are minor matters and apparently insignificant. The Blue Flag is a water seeking species, and was present, where found, quite probably as the result of disturbance of the normal conditions by man, which gave it a chance to establish itself where it now is.

North of Houghton, in a somewhat extensive bog near the entrance to the Portage Lake ship canal and on its western side, was a marginal zone of Sweet Gale, standing in the shallow water. This bog was, in places, somewhat open, with areas of sedge, but in general, was covered by the Conifer-Shrub association.

Bear Lake: Another small boggy development of peat north of Houghton, was examined at Bear Lake, a sand dune lake, at the north end of section 23, T. 56 N., R. 34 W. This was the farthest north that any study was made, and is of interest on that account. The lake was shallow, with evidences of considerable fluctuation in the water level and around much of the margin there was little organic matter, except a thin coating of algal residue mixed with the fragments of shells, and of the larger plants of the lake and its shores. On such shores the vegetation was scant and of ordinary shore plants such as Rushes, Small Spike-rush, Willows and Sedges. Above this strand-flora however, was a fairly constant zone of White Cedar, Sweet Gale, and Cassandra, a foot or more above the water level, which was probably high at the time the lake was visited, because of a very heavy rainfall a day or two before. In a slight embayment on the east side of the lake, was a small quaking-bog which was covered by the Slender Sedge and Sweet Gale on the shoreward side, the latter forming a dense fringe against the Alder zone on the shore. With the Sweet Gale was some Cassandra, Sweet Flag, Marsh Cinquefoil, and a little Sphagnum. Lakeward of the Sedge area was a zone of low plants, mostly a small slender species of Spike-rush, which covered the ground over much of the zone, but had associated with it the Horned Bladderwort, Dulichium, the Bulb-bearing Water Hemlock, Cat-tail, Yellow Pond Lily, growing in the marsh, scattered plants of Lake Bulrush, and along the edge of the water, a slender form of the Broad-leaved Arrow-head. The bottom of the lake was 6 feet below the surface of this bog. Growing in the water at some distance from the shore, were the Yellow Pond Lily, and in places, the Lake Bulrush. In this bog it was difficult to determine whether the plants now on the surface were actually building a mat out from the shore or whether the present structure was built by other plants which had been killed out and their places taken by the present association, but the structure was very weak, as if formed from very frail plants, and it was possibly the result of the growth of the rootstocks of the Spike-rush. As has been noted, the Slender Sedge was shoreward of this part of the bog and Sphagnum, the little which was present, was still nearer the shore, so that here, as elsewhere, it was playing no part in the formation of the peat, except in a very superficial way, after the surface of the deposit had been raised above the water level by the growth of other plants.

Buried Peat on the Shore of Lake Superior: In connection with the work at this point, it may be of interest to mention the occurrence of a stratum of peaty material which is exposed in the face of a recently cut bluff on the shore of Lake Superior about a half mile from Bear Lake.

A storm, a few days before, had cut into the base of the bluff and about 8 feet above the water level, on top of a mass of reddish till, was a layer of black, fine-grained, peaty material nearly a foot thick. Above this, was a stratum of gravel 2 feet thick and then wind-blown sand to the top of the bluff.

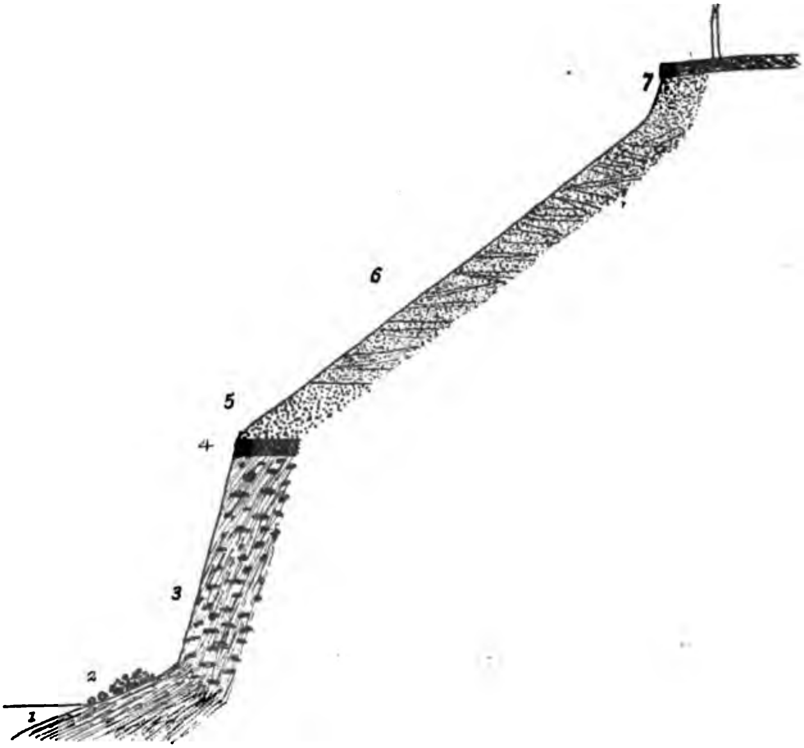


FIG. 15. Section of bluff, shore of Lake Superior 2 miles east of Portage Canal, showing buried peat bed.

1. Water level.
2. Shingle beach.
3. Reddish till.
4. Peaty bed.
5. Gravel stratum.
6. Dune sand.
7. Soil layer.

The peat was probably formed in a shallow bar-formed pond, which later was invaded by storm waves which covered it with the gravel which now overlies it; subsequent changes heaped up the sand over this and lowered the level of the water, or raised the shore, and only recently has the lake begun to cut into the deposit again. But for the gravel stratum it would be a probable assumption that the peat was formed in a shallow depression between dunes, and covered with wind-blown sand, but the gravel above the peat was too coarse to be blown about.

Lakes Near Marquette.

At Marquette two types of growing bogs were studied, those about small lakes and those which were developed between sand dunes, along the shore of Lake Superior. But two lakes were studied here, the first in the N. E. ¼ of section 10, T. 48 N., R. 25 W., and the second on the line between sections 3 and 4 of the same township. In the first, there was a considerable marshy area on the west side, and the usual peat-forming plants more or less well distributed all around. The chief marginal plant around the greater part of the water was Sweet Gale, which also grew in crevices of the rock outcrop at one point on the lake up to a height of 4 feet above the water. In a selected area, it was found that the Yellow Pond Lily was growing in the water, and shoreward a zone of Slender Sedge, then one of Dulichium and above this was a zone of shrubs, Sweet Gale and Cassandra near the water level, and Common Alder and Mountain Holly above it. This gave each of the usual zones found in many lakes a representation, but in this one, the zonal arrangement was not uniform about the entire pond, nor about much of it, the shrub zone being the one most generally present, as noted above. Some interesting relations were noted here among which were the following: The mature part of the bog had a Conifer-Shrub society, mainly Tamarack and Common Alder; Cassandra and Sphagnum were not found in the parts of the Tamarack-Alder association examined, although Cassandra remains were abundant, suggesting the possibility that the plants had been killed by the shade of the Alders, since the species is sometimes present under pure Tamarack growth. In the same amount of shade where the Cassandra was wanting, the Labrador Tea, Low Blueberry, Wintergreen and Creeping Snowberry were abundant.

The shrubs of the marginal zone, which included Cassandra, Sweet Gale, Mountain Holly, Andromeda, and Labrador Tea, all grew up on the banks of the lake, above the peat of the margin, to sand, and flourished in it, and with them grew Meadow-sweet and Jack and Norway Pines. The Labrador Tea and Cassandra, in the dryer parts of this zone, were associated with the Common Brake, the Low Blueberries, Trailing Arbutus, Wintergreen, Prairie Willow and Jack Pine.

Cassandra was also found growing in crevices in the rocks here, 3 or 4 feet above the water, with Cranberry, Huckleberry, Low and Canada Blueberries, Bearberry, Three-toothed Cinquefoil and the Sweet Gale. These dry-ground plants, higher up on the rocks, were dominant, but were about equal in numbers with the others, where the two types come together and the overlapping area formed a well marked tension zone.

The second lake was quite different in its state of development, having a sedge marsh all around the margin, varying in width in different parts, however. In the rather shallow water was a considerable amount of Yellow Pond Lily, shoreward of which was a zone of Lake Bulrush, then one of the Slender Sedge, with occasional areas of Dulichium and of Sweet Gale bushes, among which Reed-grass was of frequent occurrence; the shoreward border of the Sweet Gale here also having the tall stems of the Reed-grass frequently showing as an associate. This zone is bordered by a good growth of Jack Pine, which covers the high ground in this locality.

From these descriptions it is evident that the lakes about Marquette are again not especially different from those of other parts of the region studied, and that the same plants that have been pointed out as being active in the formation of peat, and in filling and covering lakes, are active here, and no others were especially important or significant in the processes.

Lakes and Bogs Between Newberry and Grand Marais.

The region about, and especially to the north of Newberry, was next visited, in company with Mr. Frank Leverett of the U. S. Geological Survey, in order to study conditions in a region of extensive peat deposits.

The Great Swamp: The great swampy area between Eckerman and Newberry deserved special attention and a much more extensive study than could be given it, but from what was seen, it seems probable that the swamp is formed in a very flat, poorly drained, sandy plain, with a great number of low sand ridges which may have been either wave or wind formed, and which farther check the outflow of the water and hold all the rain which falls upon them. The peat beds seem very generally shallow, a foot or two deep, although much deeper in places, and it is evident that draining, followed by drying out, would reduce the thickness to a few inches.

The greater part of this area, except where beavers built dams and flooded considerable areas, was probably originally covered by mature swamp plant societies, with Cedar, Spruce and Tamarack as the dominant elements, before fires and lumbering produced the many changes which are apparent. At present, however, the places which have been burned over show bog and swamp societies in various stages of rejuvenation and it is possible to get some idea about the way in which plants have built up peat here. The sedges, grasses, Cat-tails, Sphagnum and shrubs all seem to play about the same part here as they do around the borders of lakes, and one sees a sedge marsh with a zone of shrubs around its border, and Sphagnum beneath the shrubs, or in another place, a broad, flat area covered with Blue-Joint Grass or Cat-tail, according as the surface is high or low above the water level, and in uncleared or unburned areas, or those less recently burned, extensive stretches of Cassandra or Cedar, Spruce and Tamarack swamps. Reading past history in the light of present developments makes it seem probable that these extensive and often shallow deposits of peat were largely formed by sedges and grasses, growing in wet or flooded soil, until the deposit grew nearly to or above the water level and then the shrubby plants and coniferous trees gradually covered the ground.

Small Lakes: In the region north of Newberry, several small lakes were visited, of which two or three will serve as examples. The first was a small kettle hole lake on section 33, T. 47 N., R. 10 W., in the morainal region, which was here covered by nearly unbroken hardwood forest. The open water had a considerable number of plants of the Yellow Pond Lily and the Water Shield forming an interrupted zone. Shoreward, around the margin, was a zone of Andromeda and Cassandra pushing out by means of their long branches into and over the water, in the manner described in detail elsewhere with Fig. 13. A short distance back from the edge of the water, Sphagnum and the Pitcher Plant and some other herbs were present, and with them were noted the Labrador Tea, Pale Laurel and other shrubs, and near the shore a dense growth of Spruce and Tamarack. This heath and conifer association was not studied in detail, but no important variation from usual associations were seen, except, it may be of interest here, to note the occurrence on the shoreward margin, of the Choke-berry and White-rod, which had not been found in this relation before, except in a few cases, where the Choke-berry occurred alone in a similar habitat. The Heath zone was practically unbroken around the entire border of the pond, but it was usually not more than a rod or two wide.

McLeod's Lake, 10 miles north of Newberry. This was also in the morainal region, so that it may be compared with the other. It was a larger body of water than the first and on the north side had a narrow sedge marsh. On the east side little if any sedge was visible, while in some places on the west side there were patches of Cassandra growing out on the margin of the open water. In a few places on the north side, shoreward of the sedges, were areas of Cat-tail, and some were noted also upon the western shore, where were also seen stools of Blue Flag, Sedge and Bur-reed. In the water was a quantity of a small Pondweed, the species of which was not determined. The most remarkable thing about this lake was the presence in the water to within a few inches of the surface, of a finely divided ooze, which was so soft that it could be easily penetrated by sticks to a depth of several feet, and which seemed to be of the same nature as the algal deposit already described. Here, however, the owner reported that there was a deep deposit of marl below the ooze, which latter was so soft in the deeper parts of the lake, that fish readily swam through it. But a very small part of this basin had been filled by the higher plants, and the steep high banks come down abruptly to the edge of the water in most places, with no peat terrace, and very little beach. The surrounding hills were covered with hardwood timber except where this had been cleared off.

Stuart's Lake: The most extensive bog seen about a lake in this region, was at Stuart's Lake a few miles northwest of the Half-Way House and McLeod's Lake. This was a larger basin and lake than either of the others described, and had been extensively filled at the eastern and southern sides. On the south side was a dense hardwood forest, but on the east and north sides, were steep banks which had formerly been covered with a good growth of Pine, now represented by stumps and scattering groves of trees of small White and Norway Pines. Plants of the Yellow Pond Lily and a Pondweed were abundant in the water not far from the edge of the bog on the eastern side and formed a thinly covered zone on a part of the north side as well. The advancing plant on the margin of the water was Cassandra, and the same shrub was exceedingly abundant in the bog as well. The Cassandra marsh, as one proceeded shoreward across it, first had Sphagnum and a mixture of other herbs and shrubs, then scattered, small and stunted Spruces and Tamaracks, and over quite a large area at the eastward end, larger, but still stunted White Cedar, Spruce and Tamarack, forming an open sparse growth. Below, covering the ground, was a dense growth of

Sphagnum often built up in hummocks 2½ to 3 feet above the water level. In the depressions between these was an abundance of Virginia, Cotton-grass, and Wool-grass, with the Sheathed and Slender Cotton-grasses scarcely less common. On the taller hummocks, the Hair-cap Moss was commonly the plant making the top stratum, while the Labrador Tea, Cassandra, Pale Laurel, Choke-berry, Mountain Holly and Cranberry, with the Three-leaved Solomon's Seal, Magellan's and Three-seeded Sedges, the King and Cinnamon Ferns, and Pitcher Plant were here associated with the conifers, the shrubs growing chiefly on the hummocks.

On the north side was a steep, sandy bank rising about 30 to 50 feet above the lake, and covered by a series of groves of Norway Pine, with dry-ground shrubs and herbs. At the foot of this slope was a narrow terrace of peat, from less than 10 to more than 20 feet wide, bordered by a well marked ridge of the same material on the lakeward side, formed by ice-shove during the winter. This ridge was 2 or 3 feet high, and, with the bog behind it, was covered by Sphagnum, Andromeda, Cassandra, Huckleberry, Winterberry, White-rod, Labrador Tea, Canada Blueberry, Mountain Holly, and Choke-berry forming a dense growth. The Choke-berry, Andromeda, Cassandra and Winterberry grew down over the lakeward side of this ridge and into and over the water to a depth of two feet. The peat here was a shallow, superficial coating, and in places was wanting entirely, where the sand plants came down to the water, which seemed higher than normal.

Lakes at Deer Park Life Saving Station: The largest of these is between 30 and 40 feet above Lake Superior and has sandy bottom and shores. In the water were White and Yellow Pond Lilies, two or more species of Pondweed, the Slender Naias, Bur-reed and a slender form of Arrow-head. The principal plants along the margin were Sweet Gale, and the Common Alder. In no place around this lake did there appear to be any filling by peat, nor in another smaller one lying a short distance to the west. This is in marked contrast to conditions in various lakes and swamps between Deer Park and Grand Marais, where, in the borders of some of them, were found interesting mixtures of the high ground and bog societies. In one sedge marsh (in which the Slender Sedge was dominant) with a Cassandra border, the Cassandra ran up on the bank to a height of 4 feet above the water level, into the zone of Jack Pine and grew with the Blueberries and Dwarf Sand Cherry. The Cassandra did not appear in the marsh at all, except on logs which had fallen into it, and thus furnished elevated spots on which the shrubs established themselves, clearly indicating their preference for dryer conditions than the marsh furnished.

Lakes Between Grand Marais and Newberry: In crossing the country from Grand Marais to Newberry, a number of small, as well as large lakes, were visited and briefly examined. One of the larger lakes was Island Lake; this had a sandy shore where it was not covered with plants, in places 10 to 20 feet high, but generally it was surrounded by a peat terrace from 10 to 50 feet wide, or, in places expanding into a broad marsh. In coves and indentations in the margin, there were colonies of Yellow Pond Lily, but no marked zone of this plant was seen. The marginal zone was of sedge, apparently the Slender Sedge, which had a strong admixture of Cassandra and Andromeda. In the border, between the sedge and shrub zones, Sphagnum was present and was abundant in the shoreward shrub zone which was here made up largely of Cassandra, Andromeda and Pale Laurel, with "islands" of White Pine, Black Spruce, and Tamarack. Near the shore there was an abundance of Creeping Snowberry, and Withe-rod. The herbaceous plants noticeable in the shrub zone, were the Few-seeded Sedge, Virginia Cotton-grass, and Pitcher Plant. Where the shores were high the Cassandra was often growing in from 1 to 2 feet of water. The water level seemed recently to have risen here, but the marginal plants were in no way suffering from the excess of water when the lake was visited and apparently even if the elevation of the water were permanent there would be little change in the relations of the plant zones, except that sedges might establish themselves a little more quickly among the shrubs of the present marginal zone, than they would be able to on the bare shore.

A small lake east of Island Lake had a peculiar appearance because of the shallowness of the water and very numerous small islands of plants scattered over the surface. The formation of these islands was due to a sedge, probably one of the turf forming species but this could not be positively determined, as the islands were inaccessible. On the sedge foundation were growing Andromeda, Cassandra, Pitcher Plant, and the Virginia Cotton-grass. Other plants were present but could not be identified with certainty. The marginal plant along the shores of this lake was Dulichium, growing upon the bottom in shallow water. Shoreward of this was a zone of Slender Sedge, one of Cassandra, which in turn gave place to a clearing society in places where White and Norway Pine formerly grew, or to Balsam, Hemlock and various hardwood tree species, where the soil was moist and loamy, and there had been no fires. It was difficult to understand how the small tracts of plants called "islands" above, could establish themselves in this lake, at the present stage of water, and it seemed almost certain that they had not done so, but had started in some period of low water, and had been able to hold on during the rise of the water. Such islands must serve as nuclei of dispersal for the plants growing upon them, and from them there can be little doubt that the oozy bottom of the lake will be covered much more rapidly than from the margin alone unless there should be an elevation of the water sufficient to submerge them and their plant societies entirely for a long time.

From the foregoing evidence it seems apparent that conditions in the swamps and lakes of the region between the railroad and Lake Superior in the great swamp district of the Northern Peninsula are practically identical with those in the other parts visited, and that the same plants as noted elsewhere and in practically the same relations are engaged in building up peat deposits.

More than anywhere else, perhaps, is the importance of water in the process of peat formation impressed upon one, for here, even in very sandy land, if the water level is usually at, or near, the surface, or slightly above it, a shallow layer of peat is formed, even when almost no humus at all is formed upon slight sand ridges a foot or two above the water in and around the depressions, as is very frequently the case, especially in the extensive swamp area mentioned above.

Trout Lake Bogs: While none of the lakes about Trout Lake Junction were studied, the extensive bogs lying along the railroad, northwest of the Junction, were visited. These lie in depressions between nearly parallel ridges of wind-blown sand, which are built up on a gentle slope and each ridge acts as a sort of dam to hold the water back from running off down the slope. The peat in these depressions was shallow, said by section men on the railroad to rarely exceed 4 feet in depth, and usually to be about one foot, and, as sand was commonly exposed in the bottoms of the railroad ditches, this statement was probably correct. Many of the bogs were in the climax condition, and such were characterized by a rather dense growth of Black Spruce, as the dominant species, growing to a height of about 40 feet, and having a maximum diameter of 12 inches, but usually of from 6 to 8 inches. The best trees grew on the sides of the low sand ridges, about 3 feet above the water level in the bog. Above the spruces on the ridges, Norway Pine was the dominant species, while the Jack Pine was mixed with both the species, and in places formed dense pure stands in the bogs, entirely replacing other species of trees in such places. Under the spruces on the sand ridges, as well as on the peat, was an undergrowth of Labrador Tea, waist high, and with it Withe-rod, Cassandra, Choke-berry, Mountain Holly, Mountain Ash, Canada, Low Black and Low-bush Blueberries, and the Common Brake. Below these, were Hair-cap Moss, Trailing Arbutus, Wintergreen, Goldthread, Bunchberry, Creeping Snowberry, Clintonia and Wild Lily-of-the-Valley, with some Sphagnum in the hollows. In the lower parts of the swamps, Sphagnum is more abundant and covers the ground. In one place where a test was made, in such an association, there were only 2-4 inches of organic matter or humus above the underlying sand. In some parts of this area the Labrador Tea was found growing up the sides of the ridges, to a height of about 6 feet above the water level, associated with the Common Brake and the Blueberries, and it was very thrifty in such places, reaching a height of about 3 feet. It was generally above all the other bog plants, often forming a zone above the Cassandra and Pale Laurel on the ridges, and was not noted at all in the moister parts of the bogs, except on sand knolls; the Pale Laurel was found growing on the ridges higher up than Cassandra, although in some places the latter species was found on the railroad embankments as high as five feet above the water in the ditches.

In a series of bogs, about 4 miles from Trout Lake, the bog surface was higher on the east side of each successive ridge than on the west side, the general slope being to the west. In some of these bogs, the surface had been burned over or cleared, and in such, Cassandra often formed the dominant plant, but in others the Cat-tail occupied the ground, or grew with the shrubs between the stools. Sphagnum was sometimes present, and various Sedges and the Cotton grasses were more or less common. Not infrequently, where there had been no disturbance of relations by man, the depressions were covered by a Spruce-Tamarack or Pure Spruce association. The tops of the ridges between bogs were covered with White and Norway Pines, with Spruces growing half way up the sides.

For some distance, in a district somewhat nearer to Trout lake than that just described, the Jack Pine was the most frequent tree in the bogs, growing with the same shrubs which are commonly associated with Spruce and Tamarack in similar situations. The trees were growing rapidly and were in denser stands than Tamarack or Spruce usually develop in such situations and were from 6 to 9 inches in diameter. It seemed probable that this species had established itself in the bogs after some severe fire during a dry time, and had afterwards been able to maintain itself in competition with the slower growing swamp trees, after the water level rose again.

The Formation of Peat Near the Shores of Lake Superior.

But a single opportunity presented itself to study marshes near the shores of Lake Superior; at Marquette a series of observations were made on some marshes formed in shallow depressions formed by cutting off a portion of Lake Superior by sand bars in the vicinity of Presque Isle Park, and in the hollows between sand dunes in other places.

At the end of the electric railway to the park, near the ore docks, was quite an extensive wet sedge marsh, formed by the growth of the Slender Sedge. Upon the marsh, growing with the Sedge in a foot of water, were scattering plants of Andromeda, Myrtle-leaved Willow, Marsh Cinquefoil, Buckbean, Bulb-bearing Water Hemlock, and low growing plants of Sweet Gale. In the ditches, by the sides of the road, were the Yellow Pond Lily, a small Pondweed, a moss, probably Hypnum, and Greater Bladderwort, and extending out from the cut turf on the sides, Creeping and Mud Sedges, Myrtle-leaved Willow, Wild Calla, and Marsh Cinquefoil, the latter extending out 5 feet from the shore, and nearly half way across the ditch. The Mud and Creeping Sedges also made good growth in the water, and about their roots and stems were collected masses of algae and Bladderwort. Among the plants of the Pondweed, which were growing in a shallow place, the Slender Sedge had grown out 3 or 4 feet in one place, but was rooted in the substratum. Shoreward of the marsh was a border of Cassandra and Andromeda, which grew up on the sand in company with Norway and Jack Pine, Huckleberry, and Low Blueberries and other dry ground species, and in one case Cassandra was building sand dunes, sending out roots as the sand was piled about it by the winds, just as it does into Sphagnum which grows up around it. It was evident in this place, that there was no difference in the plants, or in the order of their appearance in the bog or of their relations to each other or the water level from what would have been found in any shallow basin and that the formation of peat was going on here just as it would have gone on in a shallow pond inland.

In a broad marsh back of sand dunes, a half miles or more west of this station, the filling had gone a step farther and the heaths were more abundant and trees had established themselves, a group of Tamaracks being noted on one side of the marsh. The Cassandra formed a well-marked zone in places on the shoreward side; the former shore was definitely shown by a zone of Common Alders, between the bog society on one side, and the dune plants on the other. In places, the Labrador Tea, which grew within the Alder zone, was found growing up the landward side of the dunes, and associated with Huckleberry, Wintergreen, Trailing Arbutus, Bunchberry, Twin-flower and Bearberry, the latter a very common plant upon the most exposed part of the dunes.

Formation of Peat in Sand Dune Areas Near Lake Superior at Marquette.

Along the driveway south of the park, near Picnic Rocks, a study was made of a series of shallow depressions between successive dune ridges, and while but a short time could be given to this locality, a probable succession of plants and conditions for these hollows was worked out. Immediately behind the most recent dune line was a wet, open swale with water standing in it in places. This swale was, as is usual in such localities, long and narrow, and the water was probably not over 2 feet in depth. In the water were growing the Slender Sedge, Andromeda and the Marsh Cinquefoil, and upon the shores, a well-developed marginal zone of Cassandra, and shoreward of this, a zone of Common Alder, Poplars and Tamarack, running into the dryer ground association of White Birch and the three species of Pines. Shoreward of a second broad ridge of sand was another depression, in which were pools of shallow water interrupted by slight elevations of moist sand, or sometimes of humus. Around the depressions Cassandra was usually present, and with it were some two or three species of Sedge, and often near the margin of the water or growing in the margin, the Blue Flag and Nerved Manna-grass. Here, also, were found the Myrtle-leaved Willow, the Mud Sedge, Dulichium, Meadow-sweet, Wool-grass and Marsh Cinquefoil. Shoreward of the Cassandra, in the shade of the Tamarack and Black Spruce, were the Labrador Tea and Common Alder, the latter characterizing this zone. A third hollow, landward of the third dune line, was deeper and broader than the others, and was surrounded by the Slender Sedge, shoreward of which are Heaths and Conifers. Higher and older swales were visited and in some of these were small, mature bog societies, including, in some places, Sphagnum. It was apparent here, that the Sedges and some of the Grasses were the first plants to establish themselves about the water in these swales, and that certain of the bog heaths, notably Cassandra, was almost as soon on the ground.

That these shallow depressions are not all overgrown and filled up, is most probably due to the facts that they are so shallow and of such limited area that, in periods of drought, the water entirely disappears from them and leaves only the dry sand for the plants to grow in, and in wet periods they fill with water and drown out the plants which may be growing in the bottom. During the prolonged dry times the humus which may accumulate in wet periods is partly or wholly dried up, so that it often disappears entirely. It is then only in a prolonged wet cycle that the peat can accumulate sufficiently to insure filling such depressions.

Buried Peat Near Marquette.

On the outer dune, which had been cut into by a severe storm a few days before, an interesting section was obtained. The top of the dune was from 10 to 15 feet above the present gravel beach, and its foot was perhaps 20 feet from the water when it was quiet. The storm waves had cut under the base of the dune, the sand had split off and had left a vertical face. At the base of the section was a stratum 6 to 8 inches thick, of reddish brown sand that is, sand stained and cemented by bog iron; immediately above this a stratum, a foot in thickness, of peat, or humus, filled with the unchanged roots of shrubs and of Norway Pine and in the section was the partly decayed trunk of a Pine with its roots in this soil layer. Above the peat stratum was sand for about 2 feet, then a layer of Norway Pine needles well preserved, and within a few inches above this, a layer of black iron sand, from ½ to 1 inch thick. From this to the surface there were irregular strata of sand, mixed with roots of trees, grasses and the leaves of pines. (Fig. 16.)

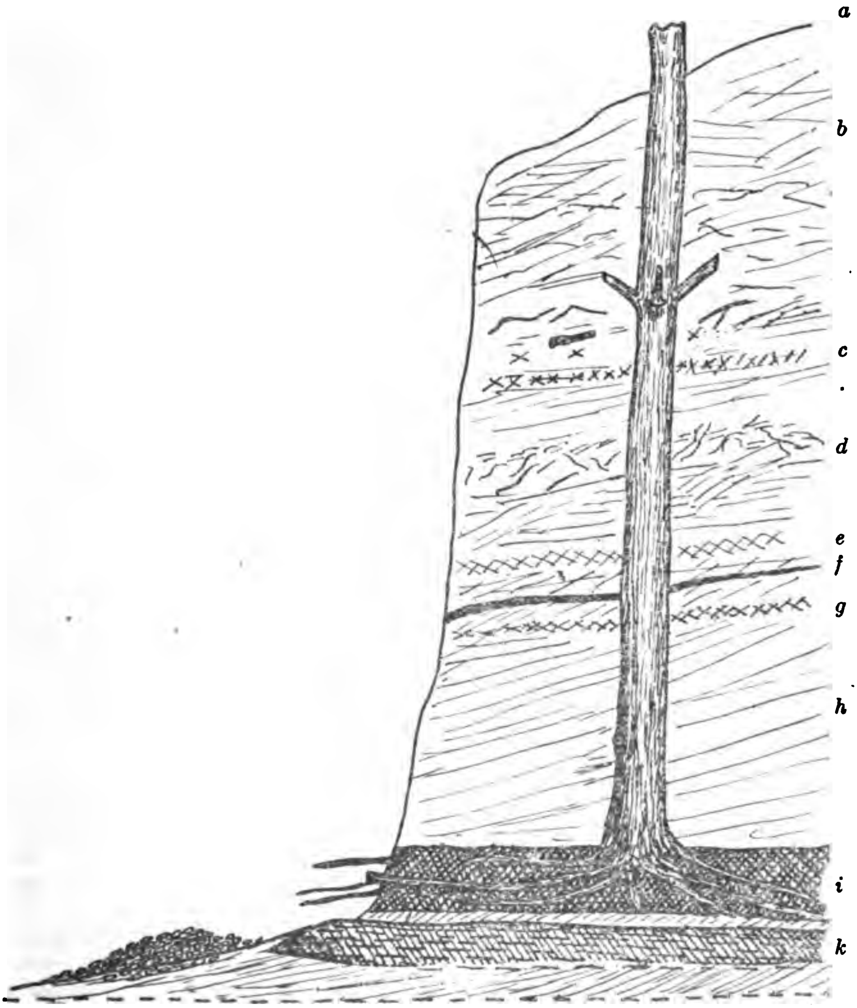


Fig. 16. Buried peat bed near Marquette, with bog iron stratum below and sand dune above. Exposure made by easterly storm.

a. Stump of buried tree.
b. Sand strata with roots and other plant remains.
c. Pine needles.
d. Sand with grass remains.
e. Pine needles.
f. Iron sand.
g. Pine needles.
h. Pure sand, cross-bedded.
i. Peat stratum, with standing pine stump.
k. Bog iron.

From this section it was evident that formerly the shore of the bay extended some distance farther out than at present, when the peat bed was being formed and that after it had reached its present thickness and trees were growing upon it, the existing dune line was established, probably as the result of cutting back the shore through a previously established dune line behind which the peat bed had been formed. The building of the dune killed the tree, and before the wood could decay it reached its present height, only to be cut into by storms during the present high stage of water in the lake. The presence of plant remains of various kinds in the sand shows that the dune was built up gradually, but that the first few feet were heaped up rapidly since in them there were no vegetable remains noticed. The bog iron below the peat bed was formed by the leaching action of the water from the soil bed, upon the iron compounds in the sand, and subsequent decomposition of the soluble organic compounds into insoluble inorganic ones. This form of action of water from marshes and forests is exceedingly common in the Northern Peninsula, where large areas of sandy soil, rich in iron, are underlain by a stratum of "hard-pan," or iron-cemented sand, at a depth of a foot or a foot and a half below the surface, which prevents rapid percolation of water, and enables the soil to support a better type of vegetation than sand usually does. This section is also an excellent one to show in a small way, how coal and iron beds may be related, and how fossils may be preserved by other means than by the action of floods, or any form of submergence by water. The stratum of black sand may be taken as an illustration of the sorting action of wind of nearly uniform velocity. It seems as if the iron sand were blown up with the ordinary kinds by heavy winds, then a time came when, for a period, the lighter grains were moved along and the heavy iron particles left behind and thus concentrated. It is also possible that the iron and sand stratum may represent a severe storm wave action, but this is not probable, unless the present dune line had grown up at the top of a beach when the water of the lake was notably higher than it is at present, for ordinary storm waves, working at the foot of a dune line, cut the sand away and do not deposit.

Formation of Peat on the Shore of Lake Michigan Near Manistique.

A study similar to that made at Marquette, was made near Manistique, under more favorable conditions, for at this station there were larger areas for observation, much less disturbed by fire and clearing than were the tracts near Marquette. The area between the town and the shore of Lake Michigan, on the west side of the river, is covered by ridges of wind-blown sand from 2 to 15 feet high above the general level, and from 50 to 500 feet broad, alternating with long narrow depressions, many of which have bogs or standing water in them. The series is approximately parallel and follows the trend of the shore of the lake. The dunes on this shore were much higher and more massive than those at Marquette, because of the more exposed position and their proximity to the mouth of a large stream, carrying abundant sediments. The dune line nearest the lake is a high, massive ridge, back from the water a distance of several hundred feet, and partly covered by dune grasses and shrubs and with scattered white pines and a few other trees. In the depression behind, or shoreward of this, was found a series of shallow ponds, long and narrow, as at Marquette, but wider and deeper.

Around the open water of these were little, narrow marshes, in which were growing the following plants: Nerved Manna-grass, Wool-grass, several species of Sedges, Blue Flag, several Rushes, Small Bur-reed, and in one place Dulichium was established. Of shrubs, the Common Alder, Meadow-sweet and Sweet Gale grew nearly to the water's edge and the dry ground species from the older, shoreward dunes, extended down to within about 2 feet of the water level; these were the Hair-cap Moss, Huckleberry, the Low Blueberries, Choke-berry and the three species of Pine. It will be observed that the water-loving plants noted above are, almost without exception, those which might be found in any wet place and that most characteristic bog and peat forming plants are absent. No filling of organic matter was observed in any part of the line of pools behind this most recent dune line.

Passing over the second dune line, on which the sand was fixed by a covering of the dry ground plants mentioned above, and by the Pennsylvania Sedge and the Bunch Grasses, a second series of pools of water was found in the depression between this and the next ridge shoreward.

These water holes had evidently been dry for a part of the year, but around them the Nerved Manna-grass and Wool-grass were the dominant plants and, in some of the hollows, the ground was covered down to within about 18 inches above the water level of that date, with a dense growth of Hair-cap Moss, which formed a well-marked line at the lower limits of its growth. Below this, and extending down into the water, was a zone of Sphagnum, the plants just covering the ground, in which were growing Blue Flag, Nerved Manna-grass, two or three species of Rushes, the Lance-leaved White Violet, and Bog Club-moss. None of these plants are known to be important as humus or peat formers except Sphagnum; in connection with the latter plant, it is interesting to note that it maintains on this slope the same relation to the water level and the Hair-cap Moss, that it assumes in bogs, where the two types grow together, i. e., it was below the latter species and near the water. Its presence in the water here may be accounted for by the rise in water, due to heavy fall rains.

The society of plants described above, was apparently a temporary or pioneer society, since most of the species are frequent on the freshly exposed banks of those lakes in which the water is receding and may appear in any moist place. The presence of Sphagnum, on the other hand, was probably significant, and through its development, the ground would probably be kept in condition for the germination of seeds of the plants of the bog societies. Several of the smaller pools in this series had the zone of Hair-cap Moss, with Sphagnum either just starting at the edge of the water, or covering the space between the water and the lower margin of that zone. Around one of the pools, the marginal plant was chiefly Wool-grass; at another the Hair-cap Moss zone was found to have Lance-leaved White Violet, Trailing Arbutus, Bog Club-moss, and a species of Panicum, and in a depression, Sphagnum 2 inches high. Below this zone were various Grasses and Sedges, and at the water's edge a zone of low Sphagnum, in which the Mud Sedge was growing, on the margin of the pool, with several species of Rushes. In the water were the Northern Water Star-wort, covering most of the bottom, and at one end a considerable colony of the small variety of the Creeping Spike-rush, growing with the common Rushes; besides these a few plants of Tall Cotton-grass, stools of Wool-grass, and what seemed to be the Floating Manna-grass, made up the list of species in the shallow water. The Sphagnum made a zone around the pond, but did not grow in the water. In this pool were Sedges capable of starting the filling, by building up peat, but they were so recently established that nothing had as yet been accomplished by them.

A much larger pool in this series and immediately adjacent to the one last described, separated from it only by a slight sand ridge a few feet wide, was in a very different stage of advancement in the development of its plant societies; Dulichium, two or more species of Sedges, the Tall Cotton-grass and Blue Flag, were growing in the water near the margin, while a small Pondweed grew in some abundance in the deeper places, and patches of an aquatic moss could be seen here and there over parts of the open water. Several Sedge islands of small size, upon which were growing Cassandra and Sphagnum and an area of Cassandra extending out 30 feet from the shore where the water was about a foot in depth, reduced the size of the pond and gave prophecy of its ultimate fate. The plants growing on the water's margin were the Blue Flag, Nerved Manna-grass, Common Alder, Winterberry, White-rod and, much more abundant than all of the others, Cassandra, which not only grew at the margin of the water, but in it, and above it 2½ feet up the bank to above the upper border of the Hair-cap Moss zone. With the Cassandra were Sphagnum, Pale Laurel and Labrador Tea.

This pool presented the nearest approach to the bog type of any in the series and was in such a stage of advancement that the end of the story of its complete filling could easily be seen; the causes of the differences seemed to be the larger size and greater depth of the basin, which enabled the water to persist in it during dry periods, and also, probably, to prevent fires from running over it and destroying such peat as was accumulated during favorable times.

The small pool next in the same line had the following conditions: The water was shallower and less in extent than in the other; growing in it were some Rushes, two species of Sedges and the Nerved Manna-grass. The aquatic Moss noted above was present in small quantities here, and there were a few Sedge islands on which the Large Cranberry was growing. There was an incomplete zone of Sphagnum at and slightly above the water's edge, and also areas of Large Cranberry, growing up on the banks to a height of 2 feet above the water level. Cassandra and other heaths formed a higher zone, and only came down to the water in a few places. The Labrador Tea was found here only about 3 feet above the level of the water in the pond. The stage of development here is evidently between that of the larger pond, with its complete shrub zone, and the smaller one, in which none of the heaths are yet present, even as islands.

Crossing over a third dune ridge and descending to the line of pools, but a single study was made. This was upon a long, deep hole, 125 or 150 feet long by 30 or 40 feet wide, in which the water was dark colored, and apparently much deeper than in any of those previously examined, especialy at one end, where the pool was scarcely 10 feet wide. The broader part of this pond was surrounded by a zone of the shrubs, Sweet Gale and Cassandra growing in the water and up to the bank and with them were the Large Cranberry, and the Mud and other Sedges as associates. Sphagnum was not noted here, although it may have been present in places, as conditions were favorable for its growth. The marginal shrub zone was thoroughly established and in places Cassandra was reaching out from the shore for a distance of 3 or more feet and, with the Sedges, formed a narrow marsh. Here, as elsewhere in the series, it was apparent that fluctuations of the water level, especially lowering it in dry seasons, had retarded peat development, but if the present conditions of moisture persisted, it seemed probable that the plants would establish themselves so thoroughly that no drought of ordinary duration would affect them.

Farther back from the shore, the hollows between dunes which were wet enough, were filled with shallow bogs, chiefly of the Cassandra and Conifer type, with abundant Sphagnum and most, if not all, of the shrubs and herbs of mature bog societies. The Conifers were chiefly small Tamaracks and Black Spruces, but not rarely the Jack Pine, and less often Norway and White Pines, were also present in these places. Three examples of these more mature bog societies may help to keep the series more clearly in mind; the first of these may be called a transition type from the early to the latest stage of development. The water of the depression had entirely disappeared before the encroachments of the plants which had built up the surface of the bog so that it was generally about a foot above the level of the water, except upon the elevations around stumps, where it was more, and in places where the Sphagnum had not yet established itself, where it was less. As indicated, Sphagnum was present, but had not yet fully covered the surface of the bog, and the characterizing plants were Heaths and the Few-seeded Sedge. The shrubs forming the association were Cassandra and Andromeda, dominant, but both rather small, the Myrtle-leaved Willow, in depressions, the Pale Laurel, on the higher hummocks, the Dwarf Birch and Small Cranberry; on the borders of the bog and on higher places within its margin, in a sort of zone, were Choke-berry, Labrador Tea, Withe-rod, Huckleberry, and Common Brake. The herbaceous plants generally distributed over the whole surface of the bog were the Few-seeded Sedge, so plentiful that it gave a decided tone to the whole association, since, in places where Sphagnum was not yet established, it formed dense patches, and persisted also in the moss-covered areas in less quantities; the Mud Sedge, with the other, and with Sphagnum as well, Scheuchzeria, in wet parts of the Sedge associations, and Marsh Cinquefoil, commonly as an important member of the same association. Young Black Spruces and Tamaracks were frequent among the shrubs in dryer places.

In the vicinity of this bog was a small pond, which was still open, and around it was a narrow marsh, chiefly covered by the Few-seeded Sedge, but with small areas of the Slender Sedge and Dulichium, along the water's edge. This Sedge marsh was bordered, on the shoreward side, by a shrub zone, in which Cassandra was a conspicuous plant.

The climax, or mature stage in the process of filling the sand dune basins here, was well illustrated by a bog, one of the many similar areas, which was covered by the following plant association. The surface was covered by a deep growth of Sphagnum, which was quite uniform in thickness, although the water level was about a foot nearer the surface at the center of the depression than near the margin. The trees were chiefly rather stunted Black Spruces, with a few White Birches and Tamaracks. The dominant shrubs were Labrador Tea and Pale Laurel, which completely overshadowed the Cassandra, which, though present, was small in size and quantity. The Low Blueberries, Choke-berry, Mountain Holly, Withe-rod, Small Cranberry, Wintergreen and Trailing Arbutus were commonly associated with these shrubs, especially on the shoreward borders of the bog, where most of the species were making their best growth. The Sphagnum in this part of the bog had reached the limits of its upward growth above the present water level and was being invaded by Hair-cap Moss and Reindeer Lichen from the surrounding sand dunes. The Three-seeded Sedge was growing plentifully in the Sphagnum in the moister places, while the Common Brake was creeping into the margin of the bog from the dry soil at the sides. Where the water level was highest, in the middle of the bog, Labrador Tea was much smaller and less thrifty than in other places, either because of the excess of water, or because of its more recent introduction into this part.

In these three localities among the older dune lines, it would seem that the second one represents a stage of filling farther advanced than any of those found in the more recently formed depressions, and the first one of the series a much farther advanced one, where the Sedges have about completed their work, and Sphagnum is beginning its work of building up the surface. In the third, the record seems to show that the Sphagnum is about through, and that the bog will soon have a plant association upon it which will have most of the plants of a fixed dune association, but with a certain admixture of such bog plants as can endure the changed conditions. If, by settling or burning, the surface is lowered, or because of increased rainfall, the water level is raised, the changes may stop, or the cycle begin again at some one of its stages, as was shown in the first of the series of three just described, where the stumps of trees are now overgrown by Sphagnum and shrubs.

It was evident, from the conditions existing in this dune area, that the development of peat can hardly be said to begin, until some of the same plants have established themselves which have been found to be forming it on the borders of lakes and other places where water is abundant; after this, the order of development is the same as that about the lakes and in other depressions; the same species, in about the same relative numbers, maintain themselves through the cycle of development, to such a stage that upbuilding of the peat is about equal to the rise of the water level, or the lowering of the surface, through compacting by settling, drying out, or other causes, when a plant association develops which is relatively permanent and this, because of the ability to perpetuate itself in favorable times and persist in unfavorable periods, is a climax society and is well represented by the one last described.

The chief difficulty which lies in the way of the rapid development of peat deposits in the sand dune basins, is that the depressions are often very small in size and shallow, which makes them easily dried out, not only through evaporation, but also because the underlying sand permits rapid lowering of the water level through percolation and therefore they are likely to greatly vary, from season to season, in the amount of water which they hold, and this, in turn, makes it difficult for the bog plants to get established, or to persist after they are established. This probably accounts for the fact that, while even the most recently formed of the basins described, must be many years old, even many hundreds, judging by its distance above and from the shore of the lake and the size and massiveness of the dune which has been built up on its lakeward side, there is yet little of the bottom covered by organic matter, and very few significant plants about its margin.

As dune basins, here and elsewhere, are commonly filled with water, even while the sides and bottom are relatively coarse sand and the older basins are usually at a successively higher level from those later formed, a few words regarding the sources and maintenance of the water level may not be out of place here, especially since the formation of peat is dependent largely upon these factors.

The water of the pools must all come from the rainfall, since there are no streams running into the basins among and in the dunes, but it is the rain falling upon the porous sand of the dunes themselves as well as in the area of the depression, which fills, or partly fills, the depression with water. This rarely, if ever, runs down the surface of the dunes, as it would in more compact soils, but is absorbed as fast as it falls and finds its way to the ground water level, and then laterally to the part of the depression where the water level is above the surface; that is, the pond. In Fig. 17 the relation of the water level in a series of dunes upon a sloping surface, is shown diagrammatically, as well as how the ground water itself prevents the water from the ponds running from one to the other through the sand. Actual study of the sands in dunes, shows that even in dry times the sand is moist at a distance of a few inches from the surface, and is saturated near the bottom at a varying height above the water table outside the dune. Around the depressions examined at Manistique, was a well-marked zone, extending usually about 2 feet vertically above the water in the pools, where the soil was moist, or wet, and the water level only a very short distance below the surface. This zone was occupied by Sphagnum, in several of the more recently formed basins, and in the older ones was the area in which the peat forming sedges first established themselves. The cause of greater moistness in this zone is close proximity of the water

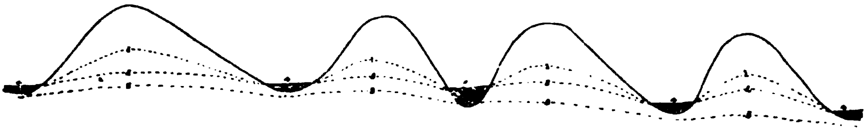


FIG. 17. Diagram illustrating maintenance of ponds on slopes covered by sand dunes in the hollows between the dunes. 1, 2 and 3 ground water level in dunes under different conditions of rainfall. 4, ponds showing the relation of surface to ground water level in the dunes. When the water level is below 2, the ponds would be shrinking, and at 3 would be dry except the deepest. The curve upwards of the surface of ground water helps to hold the pond water back, and keep it from running down the slope.

table to the surface here as it rises in a rather flat curve from the surface of the pond, to the place where the water table is highest; namely, under the crest of the dune; for the water table in ridges follows the contours rather closely, especially where the soil is as homogeneous as is wind-blown sand, except that it takes a much flatter shape, the crest constantly tending to become still lower unless the rainfall is abundant and frequent.

The statement made regarding the correspondence of conditions in bogs near the shores of Lake Superior, at Marquette, with those in lake basins, holds good for those just described, but the series at Manistique was so much more complete that all of the steps in the process of filling these dune basins were more easily and satisfactorily worked out. From the evidence gathered in these places, it seems certain that no different plants are engaged in this work among the dune basins, than are doing similar work in other depressions, whether these are large or small, except that, because of the shallowness of the depressions in the duny tracts, the aquatic plants are likely to play small if any part, since the shallow water, semi-aquatic types, are able to begin their part of the work at once. In places where the sand dune lake basins are larger, the aquatic plants are often present in great abundance, even in very shallow water, but no such lakes were found in the two districts described.

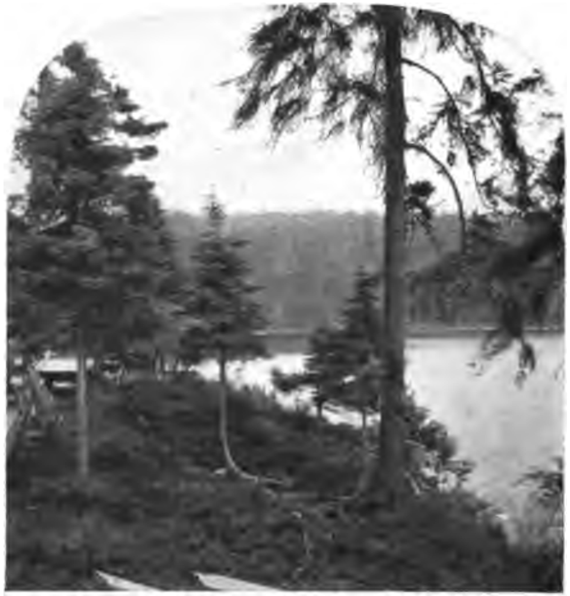
Peat Bogs of the Huron Mountains.

In August, 1906, an opportunity presented itself, in connection with other work, to visit the Archean highland, which lies in Marquette county, to the northwest of the city of Marquette, known to the early writers on the geology of the region as the Huron Mountains.

This area, which covers practically the whole of the region lying north of the main line of the Duluth, South Shore and Atlantic R. R., west of Ishpeming, as far west as the line south from the Copper Country, except a narrow border along Lake Superior, is largely made up of rock hills and rock-walled valleys, many of the latter occupied by swamps, or by small lakes. The rock is chiefly granite, with frequent dikes, by the weathering and erosion of the least resistant of which some of the principal canyon-like valleys seem to have been formed.

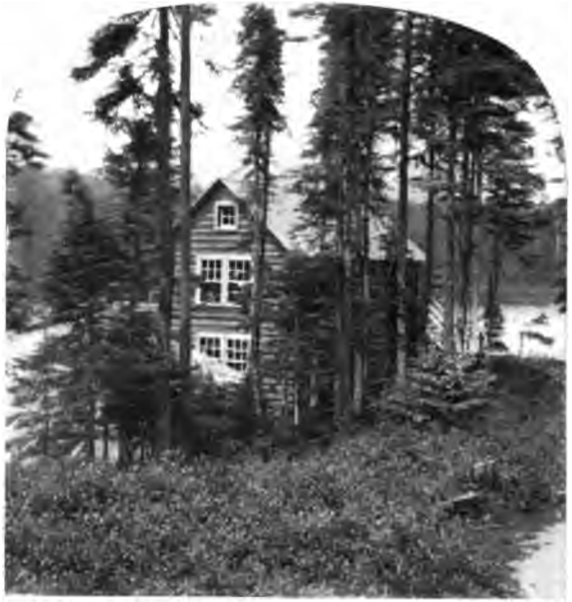
The general elevation of the central portion of this region is very considerable, the tops of some of the hills reaching an altitude of at least 1,950 feet above the sea, and it is probable, in a few cases, they may rise to 2,000 feet, thus reaching 1,350 to 1,400 feet above Lake Superior, 15 or 20 miles to the north. As a general thing, however, the hills are only 150 or 200 feet above the valleys, hence the general level is relatively high and the district is a plateau, or high pene-plain, rather than mountainous.

This considerable general elevation, together with the high latitude, gives to the region a distinctly more boreal climate than exists in other parts of the Northern Peninsula, already described in previous pages, snow accumulating to a depth of 7 feet during some winters and remaining on the ground from late October or early November till May, while even in August the night temperatures are invariably low and frosts are not uncommon in the valleys. As in other parts of the



A

Shows the end of a rock island, with peat covering, Bentley's Camp. The large tree is a Tamarack, with young Black Spruce and a Heath Society below. The hardwood forest on the shore of the lake shows in the background.



B

Shows the top of the island, with old Black Spruces and a Heath Society below.
Photographs by C. Bentley.

Northern Peninsula, there is a considerable precipitation in the form of dew and fog during the nights, so that even in rainless periods the vegetation, especially in the valleys, apparently never suffers severely from drought.

The boreal climatic conditions are clearly reflected in the vegetation, and in no part of this so evidently as in the plant associations of the bogs and of the rock outcrops. The most conspicuous and frequent forest type over much of the region is, as elsewhere in the Northern Peninsula, the broad-leaved or hardwood type, with coniferous tree species in groups, or as isolated individuals, or in pure stands of considerable extent, in favorable places, scattered through the dominant type. The broad-leaved trees, however, over much of the area, were not of good size and made rather a light open stand, as if under unfavorable site conditions, which could not be wholly attributed to moisture and soil peculiarities, but were apparently, in part at least, produced by unfavorable temperature. The species of hardwood types which were most frequent were the Hard Maple, Yellow and Black Birches, White Elm, Red Maple, White Birch, Basswood, Hop Hornbeam, and Red Oak, about in the order named, the Hard Maple and Yellow Birch much exceeding the other species in point of numbers, however.

In this region, for the first time in the Northern Peninsula, the Black Spruce was found as a common constituent of the Jack Pine forest on the sand barrens, and this species also occurred rather frequently as the dominant member of the plant societies growing on exposed rocky hills. In such places, the species reached a better development than in the swamps, growing into a tall, slender, cylindrical spire, 50 or 60 feet in height, the crown only 6 or 8 feet in diameter and the trunk attaining a diameter of 6 or 8 inches, or, rarely, even a foot. This slender columnar form of crown is unusual in the forests of the eastern part of the county, and is only approached by old Balsams; the type is well shown in some of the trees in Plate XXVIII B.

In the sand plain areas this tree and the more vigorous White Spruce, grow less tall and are, therefore, less conspicuous, especially as they are here associated with the Jack Pine growing into a similar tall, narrowly conical crown, which, taken with its short leaves and persistent pendulous branches makes it resemble the Spruces and probably accounts for its common name in this region, where it is called Spruce Pine.

The lower lying parts of the granite uplift, those which lie below 1,800 feet above sea level, have considerable deposits of glacial till which lie chiefly on the north and east sides of the ranges of hills, the tops and south and west sides of which are bare, often precipitous, cliffs, so that in looking over the country from an elevation a very different impression of its character is obtained, if one looks toward the north, from that received by looking south. If, for example, one looks at the north-facing sides of the hills, in the vicinity of the Huron Mountain Club, T. 51 N., R. 28 W., the forest-clad slopes are covered by notably fine growths of hardwood timber, here strongly mixed with Hemlock. Near the tops of the slopes, in many cases, the hardwood growth suddenly gives place to White Pine, and when the cause of this change is sought, it is found that the Pines are growing in places where the rock is at, or very near the surface. Climbing some one of the mountains back from the shore of Lake Superior in this same neighborhood and looking northward, or viewing the south-facing slopes from one of the lakes which lie nestling among these hills, and a very different scene presents itself. These hillsides, instead of being rather gentle, long and densely tree-clothed, are steep, often precipitous, bare rock with a sparse covering of White and Norway Pines, so that it could easily be imagined that one was in an entirely different region from the first. The same general conditions prevail in going inland from the Lake Superior shores, except that the Hemlock is a less frequent constituent in the hardwood forest after a few miles, and the amount of rock exposure increases in the more elevated parts of the highland, where, formerly, nearly all the hills had White Pine covering their tops, and in the most elevated parts of the plateau, their rocky sides as well. It may be noted, in passing, that the same differences in character of the north and south sides of the hills may be seen in the vicinity of Marquette, near Eagle Mills.

Types of Swamps and Bogs.

As in other portions of the Northern Peninsula, the valleys of the plateau region are covered by swamps or occupied by lakes and bogs, and here also quite extensive swamps occur on portions of the sand plains which lie between the great morainal deposits banked around the higher portions of the plateau.

These swamps of the sand plains are often densely covered with a growth of White Cedar mixed with Tamarack and Black Spruce, or in places by nearly pure stands of Spruce and Tamarack, the former so dense that little lower vegetation occurs with the taller species except in openings, where various shrubs and herbs find conditions favorable for growth.

In such a swamp, on Sec. 7, T. 50 N., R. 29 W., the following species were noted: Black Spruce, quite dense, Tamarack and Balsam Fir occasional. In more open spots among the trees, the Canada and Low Blueberries, Labrador Tea, Red Maple, White Birch and a few young White Pines. Sphagnum was found, but only in spots, and there thin and making poor growth. Cassandra occurred around the borders of wet openings in the swamp. The peat in this swamp was reddish brown and poorly decomposed, and was not tested as to depth.

Similar swamps were found along the courses of the glacial drainage valleys which cross portions of the highland, but they presented no special features, except that sometimes a swamp flora was found growing on exceedingly stony areas and even upon coarse gravels, upon which very little peat had collected, although the ground was quite full of water. The plants noted in such places were the usual swamp trees and shrubs. Some of the more accessible areas of swamps in a glacial drainage valley were seen along the Peshekeme river, near its source, along the grade of the Huron Bay R. R.

A number of lakes were visited in the divide region in T. 49 N., R. 29 and 30 W. These were usually found to have high gravelly or rocky banks, with very little swamp or bog about their margins, except in limited areas and in narrow strips. Generally these lakes are quite deep, with very little visible aquatic vegetation in them, and the water was rather dark colored, sometimes exceptionally so.

In Bulldog Lake, and another small lake connected with it, the bottom was quite soft, very near the surface in many places, and was made up for a depth of several feet of an oozy, very soft peat, which, in color and structure, closely resembled the algal peat described if it was not identical with it. These lakes lie in a long, narrow valley with generally steep rock walls, at the outlet end of which was a morainal dam. Apparently at one time there had been but a single long lake, but gradually the middle portion of the valley had become filled until only a narrow water way, or sluggish stream now connects the end portions, and even this connection has been artificially increased in width and depth through the encroaching swamp. The part of this swamp lying along the stream was rather open, with Tamaracks as the chief tree species, under which was a dense growth of shrubs, chiefly Sweet Gale, Cassandra, Common Alder and Swamp Wild Rose. The Slender Sedge, Wild Calla, Marsh Cinquefoil, Pitcher Plant and other common swamp and bog species were also noted in this area associated with the shrubs along the stream. At the south end of a small lake, in T. 50 N., R. 30 W., was a narrow but quite long bog in which White Cedar, Black Spruce and Tamarack formed the tree association, while Labrador Tea, Cassandra, Andromeda and Sweet Gale grew in dense Sphagnum below. This bog was covering what was formerly a portion of the lake but was apparently making very slow advances over the surface, as the marginal fringe of shrubs was compactly bound together by mosses and other plants and was not making the growth out into the water noted in other similar localities at lower altitudes. On the whole the lakes visited in this region were notable for the small amount of bog about them and for the absence of visible water plants, while the microscopic algæ were apparently very abundant.

An important agency in the formation of swamps in this region were those industrious little animals, the beaver, which, in this unsettled area, have become again quite numerous since protected by the game laws. Their dams were frequently seen and the very considerable areas flooded by them made travel across the stream and swampy valleys difficult; in these ponds where the dam was of recent construction, as many of them were, the dead and dying trees and shrubs could be seen standing forlornly in the shallow water.

Not only were these present ponds noted, but the filled ones or beaver meadows were not uncommon, often of considerable extent. and in various stages of advancement toward the mature tree covered swamp. In these it was usually easy to discover the long, low dam at the down stream end of the tract, often covered by shrubs, while the rest of the meadow was still clothed with grasses or sedges. In one such beaver meadow, in Sec. 2, T. 49 N., R. 30 W., around the margin, was a zone of Black Spruce and Tamarack, evidently of old growth. Bordering this on the streamward side was a well-marked zone of Blue-Joint grass, growing 3 feet high in places, and this gave place to a broad Shrub-Sphagnum zone, in which there were a few young specimens of Tamarack and Black Spruce. The dominant shrub in this area was the Sweet Gale, with which was associated Cassandra, occasional plants of Andromeda, some species of Amelanchier, or June-berry, a form of the

Tall Blackberry, and more numerous specimens of Canada and Low Blueberries, and the Small Cranberry.

The following herbaceous species were noted in this zone: Pitcher Plant, Few-Seeded and Long Sedges, Marsh St. John's-wort, Canada St. John's-wort, Alpine and Virginia Cotton Grass, White Beaked Rush, Closed Gentian, Bugle-weed and Sphagnum, which covered the ground throughout this zone, and the next. Towards the center of the meadow the shrubs were first lower, then practically wanting, giving place to an Herb-Sphagnum association, with the Long Sedge and the White-Beaked Rush the most frequent species, but growing with them were Smooth Golden Rod, larger Blue Flag, Blue Joint Grass, Pitcher Plant, Round Leaved Sundew, Rough Hair-grass, and Small Cranberry.

In the outer border of this zone there were numerous young Tamaracks and shrubs; the latter in the form of small young plants, were also abundant in the Herb-Sphagnum areas, which apparently had been heavily seeded with Sweet Gale, Cassandra and Andromeda not long before.

The dam behind which this meadow had been formed was marked by a well-defined ridge, 2 feet above the bog level, on which was growing dense, very vigorous Sweet Gale, nearly 4 feet in height.

The associations found here were evidently not characteristically different from those found in open bogs in other places, and on comparison, it will be seen that the reclamation of a beaver pond into bog, marsh and swamp goes on as does the filling of any body of water, in a definite and orderly manner.

The most interesting observations made in this region of granite hills were those made upon peat-covered rock outcrops on the hills and upon a small rock island, the top of which was at least 30 feet above the level of the water of the lake in which it was situated.

The number of observations upon this type was not large, but enough of these elevated peat deposits were seen to show that the climbing type of bog, not seen elsewhere in the studies upon which this paper were based, does exist in these cooler, more elevated portions of the Northern Peninsula, especially in the valleys, where almost nightly, during the growing season, fogs occur.

The most interesting of these peculiar bogs was a high, steep, isolated rock hill standing alone in the valley of the Peshekeme river, in T. 39 N., R. 31 W., close to the stream, upon the sides and tops of which was a good growth of Black Spruce, Tamarack and White Cedar and some White Pine, Balsam-fir, White Birch and Mountain Ash, under which were the shrubs Cassandra, Labrador Tea, Sweet Gale, Canada Blueberry and a few others. In spots, on the sides of the rock, could be seen Sphagnum, evidently thrifty and making a good growth, but the larger part of the surface, where it was not too steep for any vegetation to maintain itself, was covered by a heavy growth of Reindeer Lichen, both in the open and under the trees and shrubs. The top of this rock hill was at least 50 feet above the water of the river, which bathed its eastern flanks. The peaty covering of the rock was thin, fibrous, and with very little moisture present.

A small island (Plate XXVIII A and B), was the second of these elevated peat deposits examined and was more carefully studied than that mentioned above. The rock on which this deposit was formed was small, possibly three acres, or a little more in area, had a rounded and somewhat glaciated surface, and rose about 30 feet above the surface of the lake.

The peaty covering was usually thin, a foot or less in thickness, but, in places, was said to be at least 3 feet deep. It was made up of coarse-textured, spongy, partly decomposed, brown peat, which contained the remains of tree trunks not thoroughly rotted, and quantities of the partly decayed roots and stems of shrubs. In early August, when visited, the peat was so dry as to take fire readily and was easily blown by the wind from the openings in the ground cover.

The island had been occupied as a lumber camp some years ago and all of the large Pines had been removed from it at that time, as well as other timber trees which could be used in the various operations connected with the lumbering of Pine. Later the island had been still farther cleared and occupied as a summer camp, but, in general, the natural plant covering, except the trees, had not been seriously disturbed, save where paths had been laid out and houses built. The removal of the trees, by increasing the light, had undoubtedly increased the number of individuals of some of the lower growing plants, and decreased that of others, while with the advent of man, a few weeds and cultivated grasses had been brought in, in packing material and in other ways, from the outside world, but it was still possible to determine, satisfactorily, the original relations of the plant societies found.

Including the species growing in shallow water around the island, there were four fairly distinct plant societies present corresponding to variations in habitat. These were the aquatic, the marsh, the exposed rock, or crevice, and the Conifer-Heath society. The latter covered the greater portion of the island from a short distance above the water level, with the exception of steep and exposed rock faces at various points, and was, by far, the most important and characteristic association growing here, all the others being limited in the number of species and of individuals, and in the area which they occupied, in comparison with this.

In the aquatic society of the shallow water, the following species were noted, all sparingly represented and by very few individuals: Yellow Pond Lily, Floating Manna-grass, Swamp Horsetail, Quillwort, Floating Bur-reed and Water Lobelia. Growing in the water were other species, but these belonged properly with the next society, and are given in the following list of species making up the Marsh society at this station.

Sweet Gale (the plants growing in the water were smaller and of a lighter green color than those in the Conifer-Heath society), Cassandra, Spike-rush, Creeping Spike-rush, Dulichium, Slender Sedge (in a few small areas), Long Sedge, Wool-grass, Marsh St. John's-wort, Bugleweed, Dwarf and Canadian St. John's-wort, Small Bedstraw, Yellow Water-cress and Sweet White Violet. This society was only present in spots and narrow marginal areas of mineral or vegetable débris along the small undulations of the shore of the island, or those parts most protected from winds and waves, and, like the first society, was usually sparsely represented.

The rock or crevice society was made up of the following species, together with shrubs belonging properly to the Conifer-Heath society, present as stragglers: Low Juniper, a few plants on an open, exposed rock mass, Choke Cherry, Red Raspberry, Common Polypody, Small St. John's-wort, American Wood Strawberry, Pale Corydalis, Dog Violet, Wild Oat-grass, and Wire-grass, Mosses and Lichens.

The habitat of this group of plants was chiefly crevices and narrow shelves on the more exposed rock faces, but as there was frequently only an inch-thick covering of the peaty soil where the Conifer-Heath plants were present to the exclusion of those of the crevice society, thinness of the soil was apparently not the factor controlling the distribution of these plants, but from the situation in which they grew, it seemed probable that exposure to full light and heat of the sun, sudden and violent changes of temperature, and drought were all factors in eliminating other possible species from the places where these plants grew, and the latter factor, probably combined with rain-wash and wind effects, had prevented the accumulation of peat where these plants were found.

The Conifer-Heath society covered the larger part of the island, from the Marsh society with which it merged in some places, to the very top, wherever the rock surface was not too steep to permit the peat to form. The mature trees were all of coniferous species, although a few specimens of broad-leaved types had recently established themselves in the more open places. The trees present or represented by the stumps of recently cut individuals, were Black Spruce, dominant in point of numbers, and tallest of the trees now left, Tamarack, Arbor Vitæ, Balsam, chiefly small, White Pine, represented by some medium-sized stumps, by young individuals and a few larger ones, and Norway Pine in places where the soil was very thin and dry. The Spruce, Arbor Vitæ and Balsam were all thrifty and making as good growth as similar aged individuals in the swamps and swamp margins in the same region Where the soil was very thin the young trees were somewhat stunted.

The broad-leaved species of trees noted in young stages were White Birch, Red Maple, Wild Red Cherry, American Mountain Ash and Common Aspen. Beneath the trees there had formerly been apparently a dense growth of low shrubs, chiefly of the Heath family, and even now, the ground was completely covered by these plants, except where clearing or other artificial treatment had broken the cover. There was little zonation apparent, but the Blueberries seemed rather more abundant near the top of the slopes, and Sweet Gale and Cassandra near the water, although even near the foot of the sharper inclines, there were strong admixtures of all species.

The shrubs belonging to this society were the following: Canada, Low, and Low Black Blueberries, Labrador Tea, Cassandra, Creeping Snowberry, Trailing Arbutus, Wintergreen, Fetid Currant, Bristly Sarsaparilla, Choke Cherry, Choke Berry, June Berry, Red-berried Elder, Winterberry, Mountain Holly, Common Alder and Sweet Gale. Of these the Blueberries, Cassandra, Labrador Tea and Sweet Gale were the dominant species, the Cassandra and Sweet Gale occurring abundantly to 20 feet above the water, and Labrador Tea to the very top of the island. The other species occurred scattered over the island, some, like the Fetid Currant, Creeping Snowberry and Mountain Holly, which are commonly considered bog plants were found only on the higher parts of this island, while others were apparently accidentally present in insignificant places. In examining this list, the probability of the agency of birds in transporting seeds of most of these shrubs to the island is evident, 13 out of 18 species here having attractive and edible fruits, many of which birds are known to eat, and upon which several species were feeding during the writer's visit to this locality.

The following herbaceous species were rather sparsely present, associated with the shrubs: Spinulose Fern, Common Brake, Three-Seeded Sedge, Little Prickly Sedge, Hair-grass, Wild Oat-grass, Clintonia, Wild Lily-of-the-Valley, Indian Pipe, Wild Strawberry, Purple-leaved Willow-herb, Fire-weed, Slender Rush, Pearly Everlasting, Winged Cudweed, Sphagnum, Hypnum and other mosses and Reindeer Lichen. The Sphagnum was abundant in flat places to a height of 18 or 20 feet above the water level, while Hypnum and the Reindeer Lichen covered the ground in the dryer places. A few small areas of otherwise bare rock, on the north side of the island, were covered by a mat of Sphagnum and other mosses, and lichens, and in these it seems probable that we have an indication of the way in which the beginnings of the peat covering of the island were made, as when once the moss and lichen stratum is established, other plants soon obtain foothold and from that time on, the formation of peat may go on continuously where moisture conditions are favorable. It may be noted here that small areas of some species of Sphagnum were seen on exposed rock outcrops in several places in this vicinity, usually on northern slopes, but elsewhere in the region they were not noted.

The remaining plants found in this interesting habitat were apparently recent introductions into the native association and included the following species: Rough Cinquefoil, Red Clover, White Clover, Mouse-ear Chickweed, Black Bindweed, Sheep Sorrel, Red Top and June Grass, most, if not all, species which have been introduced with hay or packing material and only found in the clearings about the houses.

In considering the relationship of this type of habitat to others described, it is evident, upon comparison, that it is closely allied by the make up of its chief plant association to mature peat bogs of the wet type. Yet, in this place, as has already been pointed out, below the peat was an outcrop of crystalline rock, with relatively smooth glaciated and rounded surface, sloping on all sides of the water, and with no contact between the present water surface and the peat covering. The only source of water for this habitat, then, is meteoric water, precipitated as rain, snow, fog and dew, so that at times it must become very dry. In fact, as noted above, the peat, at the time of the writer's visit, in early August, was in an approximately air-dry condition; that is, with not more than 50 per cent of included moisture; so that it burned readily, and contained a minimum supply of water which was available for plants. As no rain fell in this region for some weeks after this, the peat must have become still dryer before the leaf fall of the broad-leaved species in October. This condition, which must have been constantly recurring during the time required for the accumulation of the three feet of peat found here, made the habitat, so far as the soil was concerned, an extremely xerophytic one, which could only be occupied by plants which are protected against loss of water by various peculiarities of structure, which have been pointed out in Part I of this report, and which most of the species found growing here possess to a marked degree. The chief question which arose in the mind of the writer, was how any association of plants could grow where there was so little water available, as some of the species had, where they were growing in rather coarse peat, only an inch or two deep, with only the smooth rock below, when for weeks there had been no rain.

In considering this and the related problem of the accumulation of peat in such a situation, it is probable that the location of such deposits in narrow valleys, having considerable elevation above the sea is significant, both in its relation to peat formation in such places as have been described, and to the plant species forming the covering from which the deposits are built up. In such valleys, during the day the air is warm and becomes well filled with moisture from the vegetation and soil, but at night the air is always cool, whatever the temperature may be during the day, because the cool air from the surrounding hills flows into them as soon as the sun sets, precipitating the moisture as dew and fog, and it is no uncommon thing in the large valleys containing lakes to see a small cloud of fog in the early part of the evening at the mouth of each tributary valley, while later, these small clouds spread and cover the whole valley bottom with a blanket of fog. The fog thus formed condenses still more visibly as dew upon the cool surfaces of the branches, stems and leaves of the plants, and may drop to the ground and be added to the ground water, or simply be dissipated in the morning, in which case it still aids the plants by saturating the air about them and in this way enabling them to conserve the supplies which they already have by decreasing the loss of water from their tissues by transpiration. This form of precipitation also undoubtedly helps to keep the soil moist in at least two ways besides that mentioned, first by preventing evaporation into the air, during at least the early part of the day and the whole of the night, and, second, by direct absorption by the upper layers of the peat so that the water of the lower parts is not so quickly drawn off by capillarity and evaporation as it would be in times of long drought. Another interesting and probably important factor in the early history of such deposits, is the condensation of moisture from the air, directly upon the bare surface of rocks, especially during changes from cool to warm weather, where the air is suddenly warmed up before the rocks and soils reach the air temperature. At such times the rocks will become quite wet, the moisture forming visible drops, especially in places not exposed to the direct rays of the sun, and the vegetation upon them will become as green as during a gentle rain. Such precipitation favors the growth of Lichens and Mosses and other pioneer vegetation and undoubtedly also prevents the early layers of vegetable débris formed, from becoming so dry that they would be destroyed by disintegration.

Precipitation in these forms, together with the generally low temperatures of the air during the growing season, which prevents excessive transpiration from the vegetation, and evaporation from the soil, are important if not controlling factors in the development of peat deposits like that described, and in the maintenance of plant societies upon them. That is, the climatic feature which makes the accumulation of peat on elevated rock surfaces in this region a possibility, is the high relative humidity of the air which here is greater than in other parts of the state with equal rainfall, because the temperature averages lower, since here, the elevation above sea level, is greater than in other places of the state of the same latitude. That this same factor of the climate should be taken into account in considering the agricultural possibilities of the soils, in this and adjacent regions, is obvious, because in such a moist climate the poorer types of soil will produce better crops than the same types would in a region of even greater rainfall, where the atmosphere was less moist during the summer season.

The general tendency of all low ground having sluggish drainage to become covered by peat and peat-forming plants throughout the region under consideration is attributable in part, at least, to the same cause.

In this connection, also, it may be well to point out that the close correspondence of the plant society of the elevated dry peat bed described above, with that of the older and more mature parts of those peat bogs having a wet substratum is of the nature of confirmatory evidence that these are true xerophytic habitats.

General Conclusions Regarding Peat Formation in the Northern Peninsula of Michigan.

From the foregoing descriptions of mature bogs in various types of localities, over a very considerable extent of the part of the state covered by this paper and of many classes of depressions in the process of being filled by the development of peat, it seems evident that, in general, the formation of peat goes on there, much as it does in the Southern Peninsula, but with some very interesting and important variations as to detail, the causes of which are not yet clear.

Comparison of Southern and Northern Lakes in the Process of Filling: The normal, and usual, boggy lake of the Southern Peninsula, which is being filled with plant débris, has more definitely marked zones of vegetation, and these are more fully developed and have more species of plants below the water level than the corresponding type in the Northern Peninsula. The zones of aquatic plants represented, more or less fully, in a large number of lakes and ponds in the Southern Peninsula, are the Chara zone in deep water, the Pondweed zone, the Pond Lily zone, the Bulrush zone, and the Sedge and Cat-tail zone, which is the highest aquatic zone. In the Northern Peninsula the Chara zone was not seen in a single basin, but no careful examination was made to determine its presence or absence. The Pondweeds were as frequently absent as present, and when present, were usually, though not invariably, sparse-growing and small species, in thin, or broken, zones, or as scattered plants. The Pond Lily zone was also usually poorly developed, or represented by scattered plants, or wanting, and while this is true of many ponds and lakes in the Southern Peninsula, it is not by any means so generally true. The Bulrush was also more often than not found in the shallow water of the lakes of the region studied and a very striking and important aquatic plant zone is thus eliminated from the lakes of the region. The sedge zone, then, is the one which must be considered as being the most frequently present of the aquatic, or semi-aquatic zones, but as has been pointed out, in examining the series of bogs from the southern to the northern part of the western end of the Northern Peninsula, an interesting and important variant from the type of bog which has a zone of sedges, especially the Slender Sedge, as the marginal zone, was found in those in which the shrubs, Cassandra, Andromeda, and, more rarely, Sweet Gale, were the species which were growing upon and within the water's edge, and were the plants building out from the shores and covering the open water, and apparently filling it as well. As the type was much more frequent in the northern than in the southern parts of the region traversed, it seems a fair inference that in the cooler, more humid climate of the north, the shrubs mentioned are able to grow better in the water than they can in the south. Since they can endure the conditions in the water at the margin of the mat upon which they grow, their long, rigid, stolon-like branches, which seem able to live for some years, if necessary, without rooting, are much more efficient in making advance into the open water than the comparatively weak stolons of the sedges, which, to hold themselves upright and bring their leaves above the water, must have some root attachment or grow very close together in short lengths.

It is but fair to state here, that Mr. C. C. Adams reports that on Isle Royale the bogs which were examined there, all had well-developed Sedge zones, and the hypothesis that climatic conditions are the factors efficient in producing the marginal shrub zone, may have to be abandoned as untenable, but at present no other is suggested.

Important Types of Filling: The relative absence of the larger and more highly organized seed-bearing aquatic type of vegetation from the lakes of the Northern Peninsula makes it possible for the minuter and simpler kinds to form accumulations of considerable size, and as the result of their development, a type of peat hitherto unrecognized (in this country at least) must be added to those which were known before, namely algal peat, formed almost entirely of the remains of one-celled or few-celled plants. This type has already been described on page 209 and its interesting and important bearing from the geological point of view suggested, but it may be added that the Algae probably play a more important part than has been suspected in the formation of deposits of peat in the southern lakes, where the more conspicuous remains of the tissue-forming aquatic plants, mask the minute particles of vegetable matter into which the cellular types break down. While algal filling of basins of considerable size, must be a very slow process compared with that done by the higher plants, even though the work of the latter is confined to marginal terraces which are built up by their growth. If a deposit of one twenty-fifth of an inch per year were assumed for the Algæ, it would take only 3,000 years to build a bed ten feet thick, which geologically, and relative to the time occupied in other changes upon the earth, is a very brief time, and well within the period since the basins in the drift were abandoned by the ice of the continental ice sheet. It may even be probable that the rate of building was slower than that assumed, but very much less rates may be postulated and still not be unreasonable, and out of accord with conservative estimates of the time which has passed since the last glacier disappeared from the region under consideration.

In summing up the variations in the manner in which the deeper basins are filled with peat in this region, the type in which the Swamp Loose-strife is the marginal plant may not be omitted, for while this plant was present in but a single lake among those visited, the hundreds which were not visited, may include many with this kind of marginal zone. It is not unlikely from the known distribution of the Swamp Loosestrife, that it is rare in the Northern Peninsula but it probably exists in more than a single locality, and where found is remarkably efficient in producing a strong and enduring mat over the surface of the water.

Minor modifications in the types of marginal turf formation, especially in those cases where the sedges are present, are of some importance in determining the succession of plants after the advance has been made, and the consequent upbuilding of the surface so that trees are able to establish themselves.

The important sedges of the turf building type of the marginal zone are (1) the Slender Sedge, (2) the Bottle Sedge, (5) the Tussock Sedge, (4) the Creeping Sedge, (5) the Mud Sedge and (6) the Few-seeded Sedge. Other grass-like turf-forming plants growing on the marginal zone, which occasionally are of importance are Cat-tail, Dulichium and some of the Spike-rushes, but so far as observed, these are infrequent, except in limited areas and never were found to cover the entire margin of larger ponds.

Of the sedges, the Slender Sedge is the one most efficient and frequent as a marginal species, as was the case in the Southern Peninsula, and the slow building up of the surface of the turf made by this species by its own remains and those of other plants, has been made clear, especially where it has frequently been noted as forming wide zones almost free from other species.

Factors Controlling the Width of the Sedge Mat: The width of the sedge mat, manifestly must depend upon two factors, at least: (1) the rate at which it pushes out from the margin and (2) the rate at which the surface is built up above the water level so that the species can establish themselves and crowd out the Sedge. The fact that the Slender Sedge mat is usually wide, shows that the species does build out from the shore much faster than the surface is built up. Late in the history of its development, the mat is invaded, along the shoreward margin, by shrubs or Sphagnum, or both, after which the elevation of that part of the surface is rapid.

Periodicity of the Growth of the Mat: As has been mentioned elsewhere in this paper, there are indications, very generally found, throughout the Northern Peninsula, that all the plants have periods when they advance rapidly from the shore, and other periods when the advance is checked and all the species remain where they are established, or even, in many cases, disappear, or retreat to the shore again. The most generally operative and effective cause capable of producing such results would be changes in water level, and the advances from the shore of all the species from the marginal types, to the trees, these remaining longest on the shore, seem to be coincident with the periods of lessened rainfall and low water level. In such periods the Slender Sedge marsh may be covered for many yards of its width by shrubs and Sphagnum, while the trees appear in the older parts of the shrub zone at about the same time, and the Sedge grows outward over the marginal terrace developed by various causes beyond its edge.

In wet periods, on the other hand, all the zones, except possibly the sedge zone, simply thicken up by increasing the numbers of individuals in favorable places, and make little, if any progress in other ways; or, if the rise in the water is too great, or sudden, may be set back to some higher level by being drowned out from the lower ones. Only by such changes of water level does it seem possible to account for some apparent anomalies in the intermixture of zonal plants which were frequently noted in bogs of the Northern Peninsula, where the level of the water, when observed, was too high to permit plants growing in it to establish themselves, and some of their associates were evidently of recent introduction and were properly in the habitat where they were found.

During the longer or shorter times when the zones are not making any advance, a thickening of the turf may occur, apparently because of the increase of weight upon it as the shrub and tree associations became more highly developed. This causes a slow sinking, while the surface is built up. The sinking apparently only continues until equilibrium is established and then ceases. When a new advance of the series of zones takes place, the old portion of the mat is much thicker and firmer than the new part and the line of union between the two can usually be determined not only because the plants growing in the newer part are different, and form a simpler association, but also because the newer part is less firm and much more easily shaken, on account of its greater thinness. Sometimes the tree growth is confined to the old part of the mat and sometimes the shrubs and Sphagnum mark its limits.

If the Tussock Sedge is the marginal and advancing plant, the habit which the plant has, of building its stools up above the water level, makes the conditions very different where it occurs, from those where the sedges which make a horizontal growth are marginal. The Tussock Sedge stools, as soon as they are built up a foot, or less, above the water, become the habitat of a number of plants from the Shrub-Sphagnum zone, and these soon bind the separate stools together and form a compact turf from which the Sedge itself is eliminated, so that the marginal zone here is often very narrow, and because of the height of the surface above the water level, the zone of pure shrubs encroaches upon the favorable site to be followed by the trees, almost as soon as the shrubs are established upon it, and the Sedge, the founder of the substratum, is confined to the narrow zone next the open water. The Bottle Sedge, rather a frequent marginal advancing plant, in the Northern Peninsula, is taller and larger than any of the other marginal sedges, having coarse thick, leaves and stems and it seems to build up the surface rather faster than the other species where it is found; hence marginal zones of this plant are narrow in proportion when compared with those in which the Slender Sedge is dominant. The Creeping and Mud Sedges are slender types and are usually capable of making a turf only in connection with other species, but occasionally they form narrow marginal zones and reach out into the water, where other plants follow upon them, but so far as observed, these two species never make extensive marginal mats themselves.

The Few-seeded Sedge is so like the Slender Sedge in its vegetative characters, that it is often impossible to distinguish one from the other, unless in fruit. The Few-seeded Sedge is frequent in low places in the Sphagnum-Shrub zone of bogs, and in a few cases in the more northern bogs visited, bore to that zone, the relation of a marginal plant, as if it had formed the mat upon which the other plants had established themselves. In a few cases also, it was observed in the marginal zone about open water, and there may have been others, where leaves alone were found, where this species was confused with the Slender Sedge, so it is given place here as a turf bearing species.

The manner in which shrubs form marginal zones around lakes and extend the structure of the bog, has already been described in detail elsewhere, page 235. It needs only to be pointed out here, that the purely marginal zone of shrubs is very narrow since, because of the height to which these plants grow above the water, the rigidity and strength of their stems and branches and their perennial habit of growth, other shrubs, sedges and other herbs, Sphagnum and even trees can occupy the structure almost as soon as it is established.

This statement regarding the narrowness of the purely marginal zone, applies equally well to that occupied by the Swamp Loose-strife, since it is also able to build up over the water level and form a substratum upon which most other plants of the bog type of habitat may grow.

It is evident from these considerations, that when most of these marginal species have created a habitat for themselves and have grown in it for a time, they develop by their growth, conditions which so improve the habitat that it becomes available for other species which promptly possess themselves of it, and overwhelm the makers, only to continue the process of improvement and be dispossessed in turn by other types.

This would proceed in a regular order through a definite series of changes to an end type of plant association, which would be able to hold the improved site, or habitat, against all comers, if climatic and all other conditions were absolutely uniform, so that there would be no marked fluctuations in water level, in evaporation, and in the various other important factors, which materially affect the kinds of habitat under discussion. But as has been pointed out frequently in previous pages, these irregularities do occur, and in consequence of them, the bog may reach a certain stage of development and then be set back to a much earlier one, or rejuvenated, or it may reach a mature stage, and continue in it indefinitely, the dry periods causing the surface accumulations to disintegrate sufficiently so that succeeding wet ones are only able to restore what was lost by disintegration and compacting. The plant associations in this stage of development are made up of permanent species, which can endure both wet and dry cycles, and of transient ones, which come and go with the changes of environment brought about by alternate rise and fall of the ground water level.

Still farther, a prolonged dry period may bring about a rapid development of the shoreward zones toward the open water, and an apparent skipping of the usual order of progress in the plant associations. Lastly, in the case of the associations of the mature conditions, certain plants may so raise the surface of their habitat in wet periods, that in dry ones, this becomes very dry, so that only the most drought-resisting species can permanently live in such places, and these migrate into the bogs from the sand plains. On the other hand, however, even these mature associations may slowly bring about changes of their habitat, by affecting drainage, and by producing excessive shade, so that even in such advanced stage, changes may occur. If the drainage is affected so that the water level is raised rapidly, rejuvenation will occur and some of the early stage societies will more or less quickly establish themselves.

Where the growth of tall species, such as Cedar or Spruce, is so luxuriant that the ground is strongly shaded, the lesser species which require much light, are suppressed, which may also mean that the amount of material added to the surface deposits is reduced until the upbuilding no longer goes on. When there is a large development of conifers, the shade may be so dense that no plants grow below them, and the result is a very slow upbuilding, if there is any. Again, if any agency, as wind, insects, disease, competition of neighbors, man, changes of water level, etc., remove these taller species, either as individuals or groups, the increased light usually permits the return of shrubs and herbs for a time.

Species Concerned in Peat Formation: It must also be remembered that many species of plants, as well as zones, are absent from both the marginal and aquatic areas of the boggy lakes of the north, which are present in the south. In fact, if the foregoing descriptions are inspected with this in mind, it will be found that while many species common in the southern bogs are wanting in the northern, they are not replaced, to any extent, by more northern plants, but the flora of the northern bogs are really poorer in species than in the southern, the types which do occur growing in greater numbers, and often more luxuriantly, thus fully occupying the ground.

Not all of the plants which grow in the southern bogs are southern in distribution, however, for a number of species found there in abundance, are, in the north, found growing to greater perfection outside the bogs, and in some cases at least, seldom or never in them. These plants after leaving the bogs are found first on the higher spots and landward margins, and then to take two different types of habitat, the one group going into the broad-leaved forest, where the conditions are best, while the other group seems to move out of the bogs into the dryest and poorest of sites, the sand barrens. In the first group are found the Yellow Birch, the Mountain Maple and others, while in the second, various shrubs are the most conspicuous plants, such as the Choke-berry and several heaths, some of which, as the Labrador Tea and the Blueberries, give indications, before leaving the bog habitat, of their relationship to the flora of the dry sandy soils, by always growing in the dryest, highest parts of the bogs. The structure of the leaves and other parts of these plants, as shown in another section, indicates a fitness to live in a very dry habitat.

On the other hand, if aquatics are excepted, the important, active, peat-forming plants are the same at the north, as in the south; the sedges which are the most common and important pioneer plants, are all found in the same general relations throughout their range in the region covered by this paper; the water-plants, when present, are of the same species or closely related ones of the same genera; the shrubs are of more importance at the north than at the south in forming peat as has been shown elsewhere, but their extension of vertical range, and importance, is not accompanied by any change of species, except in a few cases, in which some of the less important kinds, like Sweet Gale, do not reach the extreme southern part of our limits, but their importance, compared with other species which are constant, is very small.

Relation of Sphagnum to Peat Formation in the Northern Peninsula: Sphagnum has perhaps been mentioned, more than any other plant, in descriptions of bog plant societies in the preceding pages, because it has been given such an important place as a peat forming plant by many writers upon the subject. In studying the relation of Sphagnum to the formation of peat in Northern Michigan, several things were kept constantly in mind; the most important of these was to determine the relation of the plant to water level, where it grew under natural and undisturbed conditions, for upon this depended, very largely, its capacity to form deep deposits of peat. Because of the importance of this relation, every locality visited was carefully examined to see if Sphagnum showed any tendency to grow in water beyond the margin of the advancing higher seed-plants, as it has been reported to do, and in no single instance was it found beyond the edge of the Sedges or Shrubs which formed the marginal zone upon open ponds. Not only was this true, but in extensive Sedge zones, the Sphagnum was rarely found growing beyond the shoreward margin of the zone, where the water covered the surface of the turf, and where it was thus found, it usually grew more luxuriantly above the water level than below it. In a few instances it was growing in the water among Sedges, but in places where it was clear that there had been a recent rise of water over the whole series of plant zones present. In a few cases the Sphagnum was found growing well in the water of ditches cut through peat beds on which the moss was present as a member of the surface association, and apparently it was at home in the water, where it was seen in such situations, but even in these places, other types of plants were more abundant as aquatics than this, and the farther north the investigation of this subject was carried, the less Sphagnum was in the water, except by the accident of excessive rise of the water due to a heavy rainfall, as in the last open spot in a marsh near Houghton. Sphagnum was found, on the other hand, to appear in the Sedge zone just above the water level and to grow up from this level to a height of from 2 to 3 feet, around shrubs and other plants. At the top of the highest elevations thus built up above the water table of the bogs, another moss, the Hair-cap Moss, or even a lichen, the Reindeer Lichen, was usually found, showing that Sphagnum had reached its limit of growth in the upward direction. The moss was able then to build up a deposit to a height of a little less than 3 feet above the water and then dry ground types of plants settle down on it, and no farther development takes place, unless the water is again raised.

In the extreme southern part of the Northern Peninsula, about Menominee, there was little Sphagnum seen, even in the mature types of bogs, but farther north it was very generally present as a member of the shrub societies; and where the shrubs were pushing out over the water, the moss was among the first plants to follow along after them, but it was very rarely seen growing in the water among the branches of the shrubs, and never beyond them; usually it was found appearing first at a distance of from a yard to a rod, or more, back from the water's edge, on the turf formed by other plants. Sphagnum in this region is entirely a superficial plant, appearing rather late in the history of the development of the bogs, and rarely adds 3 feet of material to the surface. In many cases, the entire deposit of moss remains, together with the living plants, was less than a foot deep, in what seemed to be very old bogs, especially in the north, so that it is evident that the importance of the Sphagnum type of moss as peat formers in the region visited was relatively small. As in the case of other types of plants and even more quickly, because of its rapid growth under favorable conditions, the moss sooner or later creates conditions by its growth, which are unfavorable for it, and it is either replaced by other plants or survives in an enfeebled state, until the conditions change and become more in accordance with its requirements. The main factor which seemed to control the distribution of Sphagnum in the bogs visited, was, as has been stated, height of the ground water level, the amount and kinds of mineral matter present in the water or surrounding soil having apparently no relation to the occurrence of the plant, for it was quite as frequent and widespread in the bogs of the drumlin region, where bed rock was limestone and the soil and soil-waters were highly charged with calcium salts, as in the region of rock hills, where granite and metamorphic rocks furnished the greater part of the materials composing the soils, or in the region still farther north, where sands, largely derived from the Potsdam sandstone, were the characteristic soils, and the soil-waters seemed to have little mineral matter in them. In fact, as Sphagnum grows in the bogs of Northern Michigan, starting above the water level and away from the margin of the open water of lakes, and from the shoreward borders of bogs and building up a mass of vegetable débris until the living plants are at the top of a mound 2 or more feet from the water, it is difficult to see how the soil-water can affect it much, one way or the other, and it would seem as if it must get most of its moisture from the meteoric water coming to it from above, the small amount reaching it from below being sufficient to supply it with the little mineral matter it requires. Even in valley bogs along streams, the conditions are not favorable for large supplies of soil water to reach the Sphagnum-bearing part of the bog, but the moss was found growing in a few cases near springs where the water which it received was noticeably mineralized. The elevated and dry peat deposits of the Huron Mountain region seem to originate in the growth of Sphagnum and other mosses, and lichens on the bare crystalline rock, but this is by no means certain from the few observations made, bearing upon the matter, and if true but farther shows the lack of relation between the Sphagnum and the soil water. In this discussion, it is understood that no one species of Sphagnum is considered, but all which came under observation were noted, so that the statements made above are generally applicable.

Distribution and Abundance of Peat: One of the first things which strikes an observer in this region, is the number and extent of the swamps, which, because of their distinctive plant associations, are easily noticeable, and marked out from other types of soils. From a study of the map showing the distribution of the bogs and swamps of the Northern Peninsula, it is evident that the impression gained by traveling over the region is a correct one, and that swamps are an important part of the surface features, but are more frequent in some parts than in others. By far the greatest area of peat swamps, since most of these swamps are peat-bearing, in the state, is in the extensive tract lying in the eastern part of the Northern Peninsula, southeast from Munising and extending eastward nearly to Sault Ste. Marie. This area has a length of nearly 100 miles and its greatest width from north to south is nearly 50 miles, if connected, outlying areas are taken into account, but it is usually much narrower than this. This great expanse is not all swamp, but over much of its extent consists of alternating low, narrow, sand ridges, or, more rarely, clayey ones, and broad swamps and marshes. The flatness of the area, and the fact that an outcrop of hard limestone on the south has interrupted the drainage, by preventing the streams flowing out from it from cutting their valleys, seem to be the chief causes operating to make this a region of swamp. The peat, over much of this area, is very shallow, judging from observation and report, and it seems probable that a considerable part of it is not deep enough to warrant commercial development. The parts of the Northern Peninsula least swampy are the south one-third of Houghton and the greater part of Ontonagon and Baraga counties. These are regions of rather steep clay slopes and rock hills with well-drained valleys between them and conditions are not favorable for peat formation. Over the rest of the Northern Peninsula, areas of swamp are well distributed and vary in area from a few, to many hundreds of acres and the peat in them from a foot, or less, to 20 or more feet in depth. On the whole, this region is more swampy, because less well drained and more moist, than the Southern Peninsula, and the peat has accumulated in shallow deposits where there would be none farther south, or only a thin layer of humus.

The greater moistness of this region is not due, apparently, to much greater rainfall, but to a lower average temperature during the hot part of the year, and especially to the absence of long continued heated spells, which reduces the amount of evaporation from the soil and prevents drying out and complete disintegration of vegetable débris during periods of prolonged drought; cool summer nights with frequent and very heavy dews, and absence of hot drying winds, doubtless also are contributing causes in the same direction.[1]

Economic Considerations.

In considering the economic possibilities of the vast stores of peat in this region, several factors have to be taken into account, aside from the efficiency of this substance as a fuel, which may be assumed to be proven by its extensive use in Europe. First among these, is the quantity available near the centers of consumption. As will be seen by reference to the map, nearly all of the larger towns are near bogs of large extent, and as each acre covered by peat represents on the average 200 tons of prepared fuel for each foot in depth, the amount of fuel piled up in these bogs is, in the aggregate, very great.

Necessity of Careful Prospecting: On the other hand must be considered the facts that most of the surfaces of these bogs are uncleared, and are covered by débris which is cleared away with great difficulty, and after the clearing, the upper layers of the peat are so poorly decomposed, as to be of little value for use in manufacturing a finished product that could be easily handled by machinery and which would bear transportation. The quality of the deeper strata of peat of these bogs, is also such that it is doubtful if it could be economically compressed by existing methods because of the incompleteness of the decomposition, and the fact that in many of the bogs, stumps and buried logs are distributed throughout the entire depth. It would be necessary to exercise unusual care in prospecting these bogs of the north, before attempting to develop them, to determine the character of the material and its adaptability to the purposes for which it was planned to use it. The quantity is very large, the quality, in many places, is poor for use in some of the processes of preparation.

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[1] Data on these points were early published by A. Winchell and may be obtained from the Director of the State Weather Service, C. F. Schneider.

Other Fuels Available in This Region: To an observer from a comparatively treeless, settled region, the amount of forest still untouched by the axe in Northern Michigan is astounding, and it would seem as if there were fuel enough in these to last indefinitely, and at the present rate of consumption, such is the case. The experience in other regions, and even in parts of this, shows, however, that when once the forests are attacked according to modern methods of utilization, they soon disappear as sources of fuel supply, and it may not be long before wood will be as scarce in Northern, as it is in parts of the Southern Peninsula; at present, however, except in very limited areas, the wood supply is too large to warrant the development of peat resources for fuel for common uses. If there were no wood to be had, peat fuel would still have a strong competition in coal brought from the Pennsylvania and Ohio fields, as return cargoes by vessels and cars which carry iron ore from the mines to manufacturing centers, and thus supply a large part of the region with the most efficient and desirable fuel known, with which peat fuels cannot at present compete successfully.

If it were possible to establish peat fuel plants upon the same scale that they are reported in Europe, near some of the Northern Peninsula ports on the Great Lakes, it is probable that an industry of importance could be created in shipping the prepared fuel to the larger cities along the lakes, just as is done with wood and mill waste. At present, however, no such work seems feasible, although the cheap water transportation should foster such an enterprise and help to make it a success if it could once be started.

Peat Coke in Relation to the Iron Industry: A much more promising possible use for peat, which has passed the experimental stage abroad, is the manufacture of charcoal iron from peat coke. Peat is readily transformed into a form of charcoal or coke, just as wood, or soft coal is, by heating in closed oven. This substance, when made from peat, is in every way as good as coke, which it closely resembles, and possesses the great advantage of being as free from objectionable substances for iron manufacture as charcoal—in fact it is a charcoal, rather than a true coke, since peat is nearer wood than coal in its composition. Already there is a great and growing charcoal iron industry developing in the state, using enormous quantities of wood, which can probably be more economically and quite as profitably used in other industries, and which threatens the extinction of the remainder of our forests at an early date. The great areas of peat in the Menominee and Marquette iron regions, are, in the meantime, entirely unutilized and are exposed to constant danger of damage by fire and overdrainage, as their potential value is not realized and they are considered worthless, when, by following the methods used by the Germans, a very profitable use might be made of them, and of other deposits as well, since in the manufacture of the coke, the objections to which the less thoroughly decomposed peats are open, in making peat briquettes, do not obtain, as the finished product is hard and compact and does not easily deteriorate in handling. If this material could be utilized in this way, existing charcoal plants could possibly be used with but a slight modification, and the by-products, including gas, would be nearly identical in kind, with those now obtained from wood distillation. The main change which would be necessary, would be to install machinery for digging, handling and drying the peat. The general development of the manufacture of the peat coke on a large scale in this region, should be seriously considered by capitalists and others interested in the conservation of the wood supply and the utilization of what should be considered an important undeveloped resource.

Agricultural Possibilities of the Peat Bogs in This Region: In most cases, the region traversed by the writer was not sufficiently drained to permit of the use of the peat swamp land for agriculture. The swamps were still in an uncleared and unsubdued condition, and seemed likely to remain so, for several reasons, among which coldness, lack of drainage, and expense of subduing, were the most frequent given. In a few places, however, there had been some agricultural use made of the swamps with varying results. In one instance an area of swamp had been cleared, drained and put under cultivation at considerable expense, only to prove entirely useless for growing crops, because of the undecomposed condition of the peat—it was too dry for any cultivated plants to grow upon; burning off the surface layer, had been tried, but the whole deposit was so poorly decomposed that this did little, if any, good, and, in the opinion of the writer, this will prove to be the case in many of the peaty swamps of this region. The method of treatment which should prove most efficacious with land of this sort, is the use of plenty of barnyard manure, which, by introducing fermentive organisms and fungi, into the peat, helps decomposition, increases its moisture holding power, as well as furnishes readily absorbed food for the crop plants. Around Newberry, the peat has been successfully used for producing a variety of crops, and seemed, where cultivated, to be in all respects in good condition for the purpose, and the celery grown here, in this type of soil, has a well-merited reputation for its excellent quality and flavor.

In conclusion, it may be well to point out that the swamps are the last kind of lands to be fully utilized in any region, and that in many of the older and more thickly settled parts of the state, the bogs and swamps are still in a wild state and are waste land to all intents and purposes, for the reason that, in many cases, attempts to use them have been misdirected and failures on this account. This problem of using this class of land is a difficult one to solve, and while the returns are excellent, if a correct solution is found, the chances are many that failure to see some of the factors of solution, will give an entirely unsatisfactory return for the efforts made, and a few such unsuccessful attempts discourage farther effort in a given locality. If this is true, in the southern part of the state, where the bogs generally have a much better and more fully disintegrated peat, and where decomposition goes on more rapidly than in the north, it is very likely to be more frequently so in the northern part, and it would be unsafe to try cultivation of peat swamps on a large scale in this region, until the conditions to be met there have been thoroughly tested by experiments, carefully conducted after a sufficiently thorough preliminary investigation. In Europe these matters are now generally turned over to commissions or societies of trained experts, partly paid by government and partly by private subscription of land owners and all of the possibilities of a given type of lands are thoroughly investigated and tested and the results reported upon, before private individuals take the matter up. The majority of the countries of Northern Europe now have strong societies, whose sole purpose is the development of the swamp lands of the countries, and great strides have been made in rendering some of such areas productive, through the work of these organizations. Similar work ought to be done in this country, and undoubtedly will be, as the need of properly utilizing the large areas of swamp and bog lands throughout the northern part of the country, becomes more pressing, because of the exhaustion of other lands and the increase in population.

Other Uses that Might be Made of Peat: There are other uses to which the extensive peat bogs in the vicinity of the cities might be put to advantage, all, however, requiring rather large investment of capital to make them possible. Among these are the use of the substance in certain manufactures, such as paper pulp or paper, fabrics, etc.; its use in such a way is not, however, probable, when other extensive natural resources, such as the extensive hardwood forests, are not yet being developed.

The establishment of central plants on extensive bogs for the generation of electricity to be transferred to mines and mills at a distance is also one of the possible other uses which might be made of the stores of peat which have been described, but again it does not seem likely that capital will seek such an investment, until some of the many really fine waterfalls, capable of producing, in the aggregate, a vast number of horsepowers of electric current, have been harnessed and this cheap and efficient source of energy developed to something near its capacity, because the water power is more cheaply developed, and is much more permanent than any peat, or other similar deposit could ever be.

Peat, as a source of gas for heating, for use in explosive engines, and for lighting, is a possibility of no mean importance, since the gas can be generated at the bog and piped long distances, and since peat gas is rated as excellent for all purposes mentioned, especially for use in engines. In addition to the gas in such a plant, coke and various secondary products would be obtained which would add to the value of this form of the utilization of peat bogs. It seems unlikely that even this comparatively inexpensive way of developing an industry based on the peat bogs of the Northern Peninsula will be considered practicable and practical in the near future, although for years in Sweden and other parts of Northern Europe peat gas has been used with success for various purposes and is made by comparatively simple and cheap apparatus, but the sparse population, the lack of industrial development, except in certain lines, and prejudice in favor of established methods and against the innovation will tend to prevent such a utilization of peat as that suggested even in connection with mining operations, where it could be most profitably used in a variety of ways.

In this section of the report, stress has been laid upon the history of the development of the bogs, because so little was known of it in this region, and also because the technical aspects of the question are more fully developed in another section of the work.

Below is given a list of the plants mentioned in this section of the reports, giving the scientific names equivalent to the common names of species which have been listed and discussed in connection with descriptions of lakes, bogs and other features which have been considered in the preceding pages, for the use of botanists, teachers and others who may wish to be sure of the identity of the plants named.

LIST OF COMMON NAMES AND THE EQUIVALENT SCIENTIFIC NAMES OF PLANTS MENTIONED IN THE REPORT OF THE NORTHERN PENINSULA PEAT BOGS.

(Names generally correspond with those used in Beal's Michigan Flora, 5th report Michigan Academy of Science, 1904, Reprinted by State Board of Agriculture, 1904.)

1. Common Alder, *Alnus incana* (L.) Willd.
2. Andromeda, *Andromeda polifolia* L.
3. Canada Anemone, *Anemone Canadensis* L.
4. Arbor Vitae or White Cedar, *Thuja occidentalis* L.
5. Trailing Arbutus, *Epigæa repens* L.
6. Arethusa, *Arethusa bulbosa* L.
7. Arrow-grass, *Sagittaria latifolia* Willd.
8. Marsh Arrow-grass, *Triglochin palustris* L.
9. Broad-leaved Arrow-head, *Sagittaria latifolia* Willd.
10. Aspen or American Aspen, *Populus tremuloides* Michx.
11. Large-toothed Aspen, *Populus grandidentata* Michx.
12. Black Ash, *Fraxinus nigra* Marsh.
13. Mountain Ash, *Sorbus Americana* Marsh.
14. Balsam or Fir Balsam, *Abies balsamea* (L.) Miller.
15. Basswood, *Tilia Americana* L.
16. Bearberry, *Arctostaphyllos Uva-Ursi* (L.) Spreng.
17. Beech, *Fagus Americana* Sweet.
18. Marsh Bell-flower, *Campanula aparinoides* Pursh.
19. Black Birch, *Betula lenta* L.
20. Dwarf Birch, *Betula pumila* L.
21. White Birch, *Betula papyrifera* Marsh.
22. Yellow Birch, *Betula lutea* Michx.
23. Small Bishop's-cap, *Mitella nuda* L.
24. Tall Blackberry, *Rubus nigrobaccus* Bailey.
25. Canada Blueberry, *Vaccinium Canadense* Richards.
26. Low Blueberry, *Vaccinium Pennsylvanicum* Lam.
27. Low Black Blueberry, *Vaccinium nigrum* (Wood) Britton.
28. Flat-leaved Bladderwort, *Utricularia intermedia* Hayne.
29. Greater Bladderwort, *Utricularia vulgaris* L.
30. Horned Bladderwort, *Utricularia cornuta* Michx.
31. Smaller Bladderwort, *Utricularia minor* L.
32. Larger Blue Flag, *Iris versicolor* L.
33. Brake or Common Brake, *Pteridium aquilinum* (L.) Kuhn.
34. Buckbean, *Menyanthes trifoliata* L.
35. Buckthorn, *Rhamnus alnifolia* L'Her.

36. Dark-green Bulrush, *Scripus atrovirens* Muhl.
37. Lake Bulrush, *Scirpus lacustris* L.
38. Bunch-berry, *Cornus Canadensis* L.
39. Smaller Bur-Marigold, *Bidens cernua* L.
40. Bur-reed, *Sparganium Sp.*
41. Small Bur-reed, *Sparganium minimum* Fries.
41a. Submerged Bur-reed, *Sparganium simplex angustifolium* (Michx.) Engelm.
42. Pursh's Buttercup, *Ranunculus Purshii* Richards.
43. Calopogon, *Limnodorum tuberosum* L.
44. Cassandra, *Chamædaphne calyculata* (L.)
45. Cat-tail, *Typha latifolia* L.
46. Cedar or White Cedar, *Thuja occidentalis* L.
47. Dwarf Sand Cherry, *Prunus pumila* L.
48. Wild Red or Pin Cherry, *Prunus Pennsylvanica* L.
49. Choke-berry, *Aronia arbutifolia* (L.) Medic., and *Aronia nigra* (Willd.) Britton.
50. Three-toothed Cinquefoil, *Sibbaldiopsis tridentata* Rydb.
51. Shrubby Cinquefoil, *Dasiphora fruticosa* (L.) Rydb.
52. Clintonia, *Clintonia borealis* (Ait.) Raf.
53. Bog Club-moss, *Lycopodium inundatum* L.
54. Water Club-rush, *Scirpus subterminalis* Torr.
55. Alpine Cotton-grass, *Eriophorum alpinum* L.
56. Slender Cotton-grass, *Eriophorum gracile* Koch.
57. Tall Cotton-grass, *Eriophorum polystachyon* L.
58. Virginia Cotton-grass, *Eriophorum Virginicum* L.
59. Silky Cornel, *Cornus Amonum* Mill.
60. Spotted Cowbane, *Cicuta maculata* L.
61. Cow-wheat, *Melampyrum lineare* Lam.
62. Large Cranberry, *Oxycoccus macrocarpus* (Ait.) Pers.
63. Small Cranberry, *Oxycoccus Oxycoccus* (L.) MacM.
64. Bristly Crowfoot, *Ranunculus Pennsylvanicus* L.
65. Great Water Dock, *Rumex Brittanica* L.
66. Dulichium, *Dulichium arundinaceum* (L.) Britton.
67. Rock Elm, *Ulmus racemosa* Thomas.
68. White Elm, *Ulmus Americana* L.
69. Cinnamon Fern, *Osmunda Cinnamomea* L.
70. King Fern, *Osmunda regalis* L.
71. Marsh Shield-fern, *Dryopteris Thelypteris* (L.) A. Gray.
72. Sensitive Fern, *Onoclea sensibilis* L.
73. Sweet-fern, *Comptonia perigrina* (L.) Coulter.
74. Philadelphia Fleabane, *Erigeron Philadelphicus* L.
75. Spurred Gentian, *Tetragonanthus deflexus* (J. E. Smith) Kuntze.
76. Goldthread, *Coptis trifolia* (L.) Salisb.
77. Late Golden-rod, *Solidago serotina* Ait.
78. Small Goose-grass, *Galium trifidum* L.
79. Blue-Joint Grass, *Calamagrostis Canadensis* (Michx.) Beauv.
80. Floating Manna-grass, *Panicularia fluitans* (L.) Kuntze.
81. Nerved Manna-grass, *Panicularia nervata* (Willd.) Kuntze.
81a. Tall Manna-grass, *Panicularia Americana* (Torr.) MacM.
82. Tall Reed-grass, *Phragmites Phragmites* (L.) Karst.
83. Beaked Hazel-nut, *Corylus rostrata* Ait.

84. Hemlock, *Tsuga Canadensis* (L.) Carriere.
85. Cut-leaved Water Hoar-hound, *Lycopus Americanus* Muhl.
86. Mountain Holly, *Ilicioides mucronata* (L.) Britton.
87. Bush Honeysuckle, *Diervilla Diervilla* (L.) MacM.
88. Swamp Honeysuckle, *Lonicera oblongifolia* (Goldie) Hook.
89. Common Horsetail, *Equisetum arvense* L.
90. Huckleberry, *Gaylussacia resinosa* (Ait.) Torr. & Gr.
91. Ironwood, *Ostrya Virginica* (Mill.) Willd.
92. Labrador Tea, *Ledum Grœnlandicum* L.
93. Showy Ladies' Slipper, *Cypripedium reginae* Walt.
94. Stemless Ladies' Slipper, *Cypripedium acaule* Ait.
95. Pale Laurel, *Kalmia glauca* Ait.
96. Ladies' Tresses, *Gyrostachys cernua* (L.) Kuntze.
97. Reindeer Lichen, *Cladonia* spp.
98. Wild Lily-of-the-Valley, *Unifolium Canadense* (Desf.) Greene.
99. Fringed Loosestrife, *Steironema ciliatum* (L.) Raf.
100. Swamp Loosestrife, *Decodon verticillatus* (L.) Ell.
101. Tufted Loosestrife, *Naumbergia thyrsiflora* (L.) Duby.
102. Hard Maple, *Acer saccharum* Marsh.
103. Mountain Maple, *Acer spicatum* Lam.
104. Red Maple, *Acer rubrum* L.
105. Purplish Meadow-Rue, *Thalictrum purpurascens* L.
106. Meadow-Sweet, *Spiraea salicifolia* L.
107. Swamp Milkweed, *Asclepias incarnata* L.
108. Wild Mint, *Mentha Canadensis* L.
109. Small Mistletoe, *Razoumofskya pusilla* (Peck) Kuntze.
110. Monkey Flower, *Mimulus ringens* L.
111. Hair-cap Moss, *Polytrichum* spp.
112. Slender Naias, *Naias flexilis* (Willd.) Rost & Schm.
113. Hedge Nettle, *Stachys aspera* Michx.
114. Red Oak, *Quercus rubra* L.
115. Scarlet Oak, *Quercus coccinea* Wang.
116. Tall Green Orchis, *Limnorchis hyperborea* (L.) Rydb.
117. Tall Leafy Green Orchis, *Limnorchis hyperborea* (L.) Rydb.
118. Tall White Bog Orchis, *Limnorchis dilatata* (Pursh) Rydb.
119. Red Osier, *Cornus stolonifera* Michx.
120. Marsh Pea, *Lathyrus palustris* L.
121. Harthwright's Persicaria, *Polygonum Hartwrightii* A. Gray.
122. Swamp Persicaria, *Polygonum emersum* (Michx.) Britton.
123. Pickerel Weed, *Pontederia cordata* L.
124. Jack Pine, *Pinus divaricata* (Ait.) Gord.
125. Norway Pine, *Pinus resinosa* Ait.
126. White Pine, *Pinus Strobus* L.
127. Indian Pipe, *Monotropa uniflora* L.
128. Pipe-wort, *Eriocaulon septangulare* Willd.
129. Pitcher Plant, *Sarracenia purpurea* L.
130. Fringed Polygala, *Polygala paucifiora* Willd.
131. White Pond Lily, *Castalia* spp.
132. Yellow Pond Lily, *Nmyphæa advena* Soland.
133. Common Floating Pondweed, *Potamogeton natans* L.
134. Pondweeds, *Potamogeton* spp.

135. Balsam Poplar, *Populus balsamifera* L.
136. Joe Pye-Weed, *Eupatorium purpureum* L.
137. Low Raspberry, Dwarf Raspberry, *Rubus Americanus* (Pers.) O. A. F.
138. Red Raspberry, *Rubus strigosus* Michx.
139. Rush, *Juncus* spp.
140. Slender Rush, *Juncus tenuis* Willd.
141. Soft Rush, *Juncus effusus* L.
142. Swamp Saxifrage, *Saxifraga Pennsylvanica* L.
143. Bristly Sarsaparilla, *Aralia hispida* Vent.
143a. Scheuchzeria, *Scheuchzeria palustris* L.
144. Bottle Sedge, *Carex utriculata* Boott.
145. Bristly Sedge, *Carex comosa* Boott.
146. Bristle-stalked Sedge, *Carex leptalea* Wahl.
147. Creeping Sedge, *Carex chordorhiza* L. f.
148. Fox Sedge, *Carex vulpinoidea* Michx.
149. Few-seeded Sedge, *Carex oligosperma* Michx.
150. Lesser Panicled Sedge, *Carex teretiuscula* Good.
151. Little Prickly Sedge, *Carex sterilis* Willd.
152. Magellan's Sedge, *Carex Magellanica* Lam.
153. Pennsylvania Sedge, *Carex Pennsylvanica* Lam.
154. Porcupine Sedge, *Carex hystricina* Muhl.
155. River-bank Sedge, *Carex riparia* W. Curtis.
156. Sartwell's Sedge, *Carex Sartwellii* Dewey.
157. Slender Sedge, *Carex filiformis* L.
158. Soft-leaved Sedge, *Carex tenella* Schk.
159. Three-leaved Sedge, *Carex trisperma* Dewey.
160. Tussock Sedge, *Carex stricta* Lam.
161. Water Sedge, *Carex aquatilis* Wahl.
162. Yellow Sedge, *Carex flava* L.
163. Marsh Skull-cap, *Scutellaria galericulata* L.
164. Common Smart-weed, *Polygonum hydropiper* L.
165. Sneeze-weed, *Helenium autumnale* L.
166. Creeping Snowberry, *Chiogenes hispidula* (L.) Torr & Gr.
167. Sheep Sorrel, *Rumex acetosella* L.
168. Three-leaved Solomon's Seal, *Vagnera trifolia* (L.) Morong.
169. Sphagnum, *Sphagnum* spp.
170. Creeping Spike-rush, *Eleocharis palustris* (L.) R. & S.
171. Black Spruce, *Picea brevifolia* Peck.
172. Black Spruce, *Picea Mariana* (Mill.) B. S. P.
173. White Spruce, *Picea Canadensis* (Mill.) B. S. P.
174. Starflower, *Trientalis Americana* (Pers.) Pursh.
175. Northern Water-Starwort, *Callitriche bifida* (L.) Morong.
176. Water-Starwort, *Callitriche palustris* L.
177. Canadian St. John's-wort, *Hypericum Canadense* L.
178. Marsh St. John's-wort, *Triadenum Virginicum* (L.) Raf.
179. Barren Strawberry, *Waldsteinia fragarioides* (Michx.) Tratt.
180. Round-leaved Sundew, *Drosera rotundifolia* L.
181. Sweet Flag, *Acorus Calamus* L.
182. Sweet Gale, *Myrica Gale* L.
183. Tamarack, *Larix Laricina* (DuRoi) Koch.
184. Swamp Thistle, *Carduus muticus* (Mx.) Pers.

185. Touch-me-not, *Impatiens biflora* Walt.
186. Twin-flower, *Linnæa Americana* Forbes.
187. Swamp Valerian, *Valeriana uliginosa* (T. & G.) Rydb.
188. Blue Vervain, *Verbena hastata* L.
189. Kidney-leaved Violet, *Viola renifolia* A. Gray.
190. Lance-leaved Violet, *Viola lanceolata* L.
191. Marsh Violet, *Viola Le Conteana* Don.
192. Sweet Wild Violet, *Viola blanda* Willd.
193. Yellow Water-cress, *Roripa palustris* (L.) Bess.
194. Bulb-bearing Water Hemlock, *Cicuta bulbifera* L.
195. Sweet-scented Water Lily, *Castalia odorata* (Dryand.) Woodv. & Wood.
196. Water Shield, *Brasenia purpurea* (Michx.) Casp.
197. Bebb's Willow, *Salix Bebbiana* Sarg.
198. Hoary Willow, *Salix candida* Fluegge.
199. Myrtle-leaved Willow, *Salix myrtilloides* L.
200. Shining Willow, *Salix lucida* Muhl.
201. Silky Willow, *Salix sericea* Marshall.
202. Great Willow Herb, *Chamænerion angustifolium* (L.) Scop.
203. Marsh Willow Herb, *Epilobium palustre* L.
204. Winterberry, *Ilex verticillata* (L.) A. Gray.
205. Wintergreen, *Gaultheria procumbens* L.
206. Bog Wintergreen, *Pyrola uliginosa* Torr.
207. Withe-rod, *Viburnum cassinoides* L.
208. Wood-rush, *Juncoides pilosum* (L.) Kuntze.
209. Upright Yellow Wood-sorrel, *Oxalis stricta* L.
210. Wool-grass, *Scirpus cyperinus* (L.) Kunth.

List of Plants from Huron Mountains.

211. Small Bedstraw, *Galium trifidum* L.
212. June Berry, *Amelanchier Canadensis* (L.) Medic.
213. Black Bindweed, *Polygonum Convolvulus* L.
214. Bugleweed, *Lycopus* sp.
215. Choke Cherry, *Prunus Virginiana* L.
216. Wild Red Cherry, *Prunus Pennsylvanica* L. f.
217. Mouse-ear Chickweed, *Cerastium vulgatum* L.
218. Rough Cinquefoil, *Potentilla Monspeliensis* L.
219. Red Clover, *Trifolium pratense* L.
220. White Clover, *Trifolium repens* L.
221. Pale Corydalis, *Capnoides sempervirens* (L.) Borck.
222. Fetid Currant, *Ribes prostratum* L'Her.
223. Red-berried Elder, *Sambucus pubens* Michx.
224. Fire-weed, *Chamænerion angustifolium* (L.) Scop.
225. Blue Grass, *Poa pratense* L.
226. Hair Grass, *Agrostis hyemalis* (Walt.) B. S. P.
227. Wild Oat-grass, *Danthonia spicata* (L.) Beauv.
228. Rock Panic-grass, *Panicum* sp.
229. Wire-grass, *Poa compressa* L.
230. Swamp Horsetail, *Equisetum fluviatile* L,
231. Low Juniper, *Juniperus nana* Willd.
232. Water Lobelia, *Lobelia Dortmanna* L.

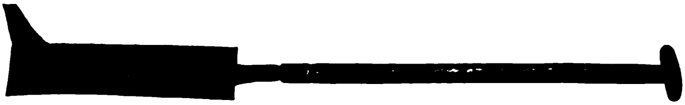
233. American Mountain Ash, *Sorbus Americana* Marsh.
234. Pigweed, *Chenopodium album* L.
235. Common Polypody, *Polypodium vulgare* L.
236. Quillwort, *Isoetes* sp.
237. Red Top, *Agrostis alba* L.
238. Bladder Sedge, *Carex folliculata* L.
239. Sheep Sorrel, *Rumex Acetosella* L.
240. Spike-rush, *Eleocharis acicularis* (L.) R. & S.
241. Marsh St. John's-wort, *Triadenum Virginicum* (L.) Raf.
242. American Wood Strawberry, *Fragaria Americana* (Porter) Britton.
243. Timothy, *Phleum pratense* L.
244. Dog Violet, *Viola Labradorica* Schrank.
245. Sweet White Violet, *Viola blanda* Willd.
246. Yellow Water-cress, *Roripa palustris* (L.) Bess.
247. Purple-leaved Willow-herb, *Epilobium coloratum* Muhl.

PART III.

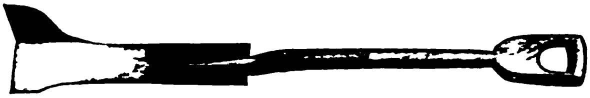
ECONOMICS OF PEAT.

BY CHARLES A. DAVIS.

A PEAT BOG.



A SLANE OF THE OLDEN TIME, ABOUT 1760.



A MODERN SLANE.

(MADE BY O. AMES & SONS, NO. EASTON, MASS.)

PART III.

ECONOMICS OF PEAT.

MISCELLANEOUS USES OF PEAT.

Introductory: Peat is a substance of such common and abundant occurrence in the regions where it is found at all, and varies so much in texture and purity that it is not remarkable that it should be put to a variety of uses for which its composition, structure and other properties make it more or less perfectly fitted, especially in countries where other forms of raw materials are scarce and expensive, and where there is an abundance of various types of peat.

Uses in Agriculture: Long before it was considered as a source of manufactured material, however, it was used as a soil upon which to grow crops, and in a number of other ways by the farmers, and methods of improving "swamp," "marsh," "moor," "fen" and "muck" lands have been important problems in agriculture from early times. Some geologists, and others, make a technical distinction between muck and peat, applying the name peat only to nearly pure deposits of vegetable matter, while the name muck is given to those which have a considerable admixture of mineral matter in the form of mud or other finely divided rock débris, but among the farmers of Michigan and adjoining regions no such distinction is made and all classes of soil, from pure peat, to that with much mineral matter mixed with it, are called muck.

Importance of Muck Soils in Michigan Agriculture: Swamp lands, largely covered by peat and muck, are estimated according to Towar[1] to form one seventh of the entire area of Michigan, and since they are quite uniformly spread over the agricultural regions of the state, so that most farms of 100 acres or more have some part of their surface of this type of soil, it is apparent that they furnish a problem of some magnitude.

In the early days of farming in the state, these areas were considered worthless and were left in a wild and much neglected condition, as many still are, but as the higher and dryer lands have become less productive, and through improved conditions, drainage of swamps has become possible, the muck soils have attracted more and more of the attention of progressive farmers, and from being considered nearly worthless, and entirely unproductive, they are now recognized as valuable and highly productive types of soil for many crops, and it is as farm land, perhaps, that peat will yield the largest returns. In spite of this fact, however, there are still great areas of such land in Michigan in a wild condition, which if they could be reclaimed, would add largely to the total wealth of the state, and to the individual resources of the owners.

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[1] Towar, J. D., Loc. cit.

Difficulties in Growing Crops in Muck Soils: It is apparent that there must be some reasons why swamp lands are neglected to such an extent, and these appear, when it is learned that in many cases there are serious difficulties encountered in securing paying crops from soils of this type, after they have been made ready for cultivation.

The causes of these difficulties naturally group themselves under the following heads:

(1) Those due to situation.
(2) Those due to the nature of the soil itself.
(3) Those due to impurities in the soil.
(4) Those due to unwise choice of crops.

Under (1) the following must be considered:

(a). The swamp is such because it lies in a situation where the ground water level rises nearly to, quite to, or above the surface of the ground, which causes the soil to be excessively wet.

(b). Swamps are usually located in depressions, and as cold air flows down hill just as water does, it accumulates over the swamps and causes unseasonable frosts during cool nights in the summer time.

(2) Peculiarities of the muck which give trouble are:

(a). The retention of vegetable structure, which gives it great power to take up and hold water, as is shown by the following table quoted by Carpenter[1] from Schubler, which gives the amount of water absorbed and retained without dripping by 100 pounds of the following soils:

	Pounds of water retained.	Per cent of evaporation in 4 hours.
Quartz sand	25	88.4
Lime sand	29	75.9
Clay soil	40	52.0
Heavy clay	61	34.9
Muck	181	25.5
Coarse peat	377 to 519	

The muck holds more then seven times as much as the sand and three times as much as the heavy clay.

(b). This water-holding property of muck makes it cold under ordinary moist conditions, since before the soil can be warmed the water which it holds must be warmed also.

(c). On the other hand, when dry, muck heats up very quickly, and radiates its acquired heat more rapidly than any other soil, making it very warm during the day and cold at night.

(d). When it has become thoroughly dried out, peat is often powdery, and very porous, and the dried particles become to a considerable degree, impervious to water, so that in dry times it does not readily become wet after it has once dried out. This property taken in connection with (c) makes it especially hard to deal with in times of drought.

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[1] Carpenter, R. C., Report Mich. Bd. of Agriculture, Lansing, 1886, p. 158.

(e). As has been pointed out in another place (page 214) peat may seem quite moist, and yet, because the water it contains is held in the remains of plant cells and tissues of which it is made, this is not available for absorption by the roots of growing plants.

(f). Because of its loose structure and lack of firmness and compactness when dry, it does not give good root hold to crops which grow tall.

(g). Because it is so wet during the fall and spring, when freezing and thawing are going on, crop plants wintered upon this type of soil are very liable to injury from frost "heaving."

(h). While very rich in plant foods, muck soils have some of the most important of these so combined with other substances that they are not readily available to the growing plants.

In this connection attention should be called to the work of the European bog and swamp culture societies and the excellent work which they have done and are doing in bringing large areas of unproductive moors and swamps into such condition that crops of some kinds can be raised on them. Since, however, European conditions of climate, of land holding, of labor, of crop production, and of markets are unlike ours, the methods used there can only be used in a general way here, but the thoroughness of the investigation of these societies, their wide scope and the excellent results make it seem that the work done by them should be followed in this country by that of similar organizations among land owners and farmers.

(3) The impurities injurious to crops which accumulate in peaty soils are of two classes, as follows:

(a). Organic acids.

(b). Mineral salts.

(a). It is a matter of common observation that muck soils are frequently so sour that they cannot be used for certain crops. This is due, in part, at least, to the presence of organic acids which are formed during the decomposition of the plant remains of which the muck is composed. The sourness seems to be due chiefly to humous acids, but ulmic acid is present in the browner types of peat and it is probable that tannic and other organic acids occur in small quantities. As all of these compounds are poisonous to a greater or less extent, it is evident that their presence is undesirable and may be harmful to particular plants.

(b). Of the mineral salts which occur in peat, and which are common in Michigan, ferrous sulphate or sulphate of iron, seems to be the most injurious to crop plants and sometimes makes the soil entirely useless. This is most often found in peat formed around springs and upon springy slopes, and the iron is doubtless derived from the water of the springs in which it exists as the carbonate.

Another soluble salt which is poisonous to crops is magnesium carbonate, probably derived from the soil below the peat and brought to the surface by capillary action, during the process of cultivation. This substance gives an alkaline reaction to the soil in which it is present, and is more likely to appear in injurious quantities after the soil has been cultivated for some time.

(4) From the consideration given above, it is evident that swamp

muck as a type of soil is not adapted to all kinds of crops, and moreover, all deposits cannot be treated alike, if satisfactory results are to be obtained from them after they are prepared for use. It must be remembered therefore, that it is often necessary for the owner of a piece of such land to make a special study of its possibilities and peculiarities before he can realize its full value and productivity.

In a large number of cases, for some years after reclamation, the surface of swamp land will be coarse textured and loose, because of the imperfect decomposition of the upper layers of the deposit, which adds to the difficulty of utilizing it to the best advantage, and it is probable that grass for hay or pasturage will generally give the most satisfactory results during the period while the surface is settling and becoming compacted and the coarse material broken down into that sufficiently fine for best agricultural use.

Methods Used in Reclaiming Swamp Lands: It is not the place here to go into the details of the methods of preparing swamp lands for profitable agriculture, but a statement of one essential may not be out of place. This is effectual and complete drainage, no simple matter, it is true, but without this, all authorities agree and experience shows that nothing satisfactory can be done.

Such soils should never be set on fire to improve their texture or composition. This point is enforced very strongly by the reply of the late Dr. R. C. Kedzie to a question as to the advisability of this practice, put to him at a Farmers' Institute in which he said in his emphatic way, "You might as well burn down your barn in order to sell the ashes."

Of the many papers contained in the reports of the Michigan Board of Agriculture, discussing methods of handling this kind of soils and of fitting them for farming and also giving results of actual experiments upon them in various parts of the state, the following are especially to be cited:

Carpenter, R. C.: The Improvement of Muck Swamps.
    Report Mich. Board of Agriculture 1886, p. 154.
Rowe, W. A.: Treatment of Peaty Soils after Drainage. 1886, p. 175.
Kedzie, R. C.: Management of Swamps.
    Bulletin 115, Mich. Agricultural Exp. Station.
    Also in Report Mich. Bd. of Agric. 1895, p. 371.
Crozier, A. A.: Wheat on Muck Land.
    Bulletin 141, Mich. Agricultural Exp. Station.
    Also, in Report of Mich. Bd. of Agric. 1897, p. 284.
Towar, J. D.: Muck Experiments.
    Bulletin 181, Mich. Agricultural Exp. Station.
    Also, in Report Mich. Bd. of Agric. 1900, p. 275.
Towar, J. D.: Beet Experiments on Muck Land.
    Bulletin 179, Mich. Agricultural Exp. Station.
    Also, in Report Mich. Bd. of Agric. 1900, p. 235.

Many other references may be found by consulting the index to the Reports from 1849-1888.

In Holland, large areas of bog, after the peat has been used for fuel, are diked and drained, and make excellent farming lands, which support a considerable population.

Peat as a Fertilizer: Next in importance, so far as agriculture is concerned, to its use as a soil upon which to grow crops, peat has a well-recognized value as a fertilizer for other kinds of soil, particularly for those which are deficient in organic matter. When used for this purpose, it is either applied directly to the soil to be enriched, or after composting it with stable or barn-yard manure, a very desirable practice for which its great absorbent power especially fits it. If used without composting, it should be well rotted and in condition such that it crumbles readily when it is air dry, not in the form of hard lumps or stringy clods, and in order to reduce the coarser kinds to this condition, it should be piled in heaps and left exposed to the weather for a year or longer, until it loses its fibrous character and breaks down into the finer grained, more friable condition. The same exposure to the air and weather should be given the black, wet and sticky peat which is found in bogs below the water level, for if it is taken to the bog and put upon the fields in lumps, it dries into hard masses and clods, which are very difficult to break up when once they have dried and hardened, and are of no benefit whatever to the land. If, however, this material is thrown out upon the surface of the bog in heaps and allowed to drain and dry and to be exposed to freezing and thawing through the winter, it becomes thoroughly disintegrated and powdery, and then may be used with good effect. The drying out upon the bog also makes the handling the material so much the cheaper, since the peat loses a large part of the water which it has in the bog, often amounting to more than 90% of the weight of the whole load, the handling and hauling of which is, in large part, waste work. If a block of this black sticky peat is taken from the bog and measured and weighed before it has become dry, and then after, the importance of this way of treating it will become apparent.

If used as material for composting, peat is mixed in alternate layers with about equal bulk of stable or barn-yard manure, to which may be added weeds, straw, or any kind of undecomposed vegetable or animal matter, piled in heaps. The fermentation of the manure induces chemical changes in the peat also, and these changes make available to crops the nitrogen which is present in the peat in an unusable form, as well as other valuable constituents.

The peat also absorbs and holds a considerable part of the ammonia which is set free in the processes of decomposition, and which would otherwise escape into the air and be lost. Because of its power to take up and hold liquids, it prevents leaching of the more easily soluble solids, some of which are very valuable plant foods, and holds them in such a manner that they are saved to be used by the crops. If used in this way a load of dry peat may well be rated, as it often is, as valuable as a load of stable manure.

The following analyses of the Michigan celery soils show how rich the peaty types of soil are in nitrogen and in other essential elements for the growth of crop plants. In these soils, which are low-grade peat, the amount of mineral matter, as shown by the sand and silicates, is much larger than in pure peats, but as they are from typical localities where extensive use is made of the muck soils, they serve for illustration here.[1]

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[1] Bulletin 99, Mich. Agricultural Exp. Station, Lansing, 1893, p. 12.

Kalamazoo Celery Soil, from Kalamazoo, Mich.

	Parts per 100.
Sand and silicates	19.16
Alumina	1.40
Oxide of iron	3.94
Lime	6.09
Magnesia	.81
Potash	.34
Soda	.38
Sulphuric acid	1.31
Phosphoric acid	.88
Carbonic acid	1.95
Organic matter containing 2.53 nitrogen	63.76
Water	6.51

Grand Haven Celery Soil. from Grand Haven, Mich.

	Parts per 100.
Sand and silicates	24.09
Alumina	1.71
Oxide of iron	3.52
Lime	5.02
Magnesia	.62
Potash	.20
Soda	.33
Sulphuric acid	1.04
Phosphoric acid	.69
Carbonic acid	1.05
Organic matter containing 2.32 nitrogen	61.73
Water	10.85

Newberry Celery Soil, from Newberry, Luce Co., Michigan.

	Parts per 100.
Sand and silicates	24.56
Alumina	2.21
Oxide of iron	1.30
Lime	4.18
Magnesia	.75
Potash	.42
Soda	.40
Sulphuric acid	.67
Phosphoric acid	.46
Carbonic acid	1.10
Organic matter containing 1.75 nitrogen	63.75
Water	7.31

In a discussion before the Michigan Horticultural Society, Dr. R. C. Kedzie,[1] than whom we have no higher authority in agricultural chemistry in this country, said in regard to use of muck for composting:

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[1] Kedzie, R. C., Report Mich. State Hort. Soc., 1883, p. 168.

"Barn-yard manure composted with equal volume of powdery muck, by placing these materials in alternate layers, then shoveling it all over once, in the spring, a month before it goes to the garden or field, will give double the volume of the manure scarcely inferior to well-rotted barn-yard manure. Such composting is not a process of dilution but a substantial addition of manurial matter. Muck contains nearly the same quantity of combined nitrogen (2%) as well-rotted manure, but this nitrogen is in the inert or inactive form. By composition with barn-yard manure, the active fermentation of the animalized matter induces fermentation of the muck and some of the nitrogen is made active."

Stable and Barn-yard Litter: Peat may not only be used as composting material to excellent advantage, but also it has extensive use in Europe, and a more limited one in this country, (1) as stable litter and bedding for horses and stock, and (2) it is drawn into barn-yards and used there as an absorbent and deodorizer. (1) For bedding and stable litter, the best kind of material seems to be the coarse, top layers of the peat bogs, including the coarse mosses and grass-like plants which often make up the surface covering. In some cases dry, powdery peat is used, especially where a deodorizer is wanted, but the ideal material for bedding is the Sphagnum moss litter. This is very light in weight and from nearly white to light brown in color, when dry, absorbs large quantities of moisture in proportion to its bulk, and forms a springy layer, which is not surpassed by any other material used for the purpose. Aside from these qualities, it is a powerful deodorizer, and a disinfectant of some value, and accumulates and holds, to a marked degree, the nitrogenous materials of the manure, most of which are entirely wasted in ordinary practice. This material should be especially valuable for use in cities, and for bedding in dairy barns where odors, all kinds of germs, and dirt of all sorts, should be reduced to the smallest possible quantity, if the cleanliness and healthfulness, and consequently the value of the product and the health of the stock, and that of the patrons, are to be regarded. It could also be used by lumber companies for bedding horses at the camps in winter.

This form of litter is already in use in some of the large cities along the coast, being so highly valued that it is imported from Europe, and there seems no reason why large quantities of it should not be used in Michigan, where it is an abundant natural product, now almost entirely unused, or even wantonly wasted by periodical burning. At the present writing, a single establishment has put this material upon the market in a few places in limited amounts. This is the plant of the Bancroft Peat Fuel and Cement Company, Lt'd., located at Bancroft.

As it appears upon the market, the material is compressed in a dried state into bales, which makes it easy to handle and ship. The peat, usually the top layers, because too fibrous and coarse for other uses, and the mosses and finer vegetation growing upon them, may be prepared for litter in any disintegrator or fiber picker, or even in a corn shredder. With a hand machine, such as are made in several places in Germany, by Martin of Offenberg, or Paul Reuss, Artem, Germany, two men can prepare several tons of peat litter in a day. With a shredding machine or mill for grinding up turfy peat, and combined with a sifting machine to get rid of the fine dust and dirt, the air-dried peat of the coarse types could rapidly be reduced to a useful product, which, after thorough drying, may be baled like straw. In developing such machinery or adapting the ordinary farm machinery to these uses, it must be borne in mind that the bog is soft and that proper foundation of piles or stone work must be provided if the machinery is heavy and is to be placed upon the peat bog; in some of the German peat presses, however, the construction is such that no special base or support is required and such devices as are necessary can perhaps be developed here, to suit special cases.

In developing large plants for this purpose, it is probable that some form of dryer might be needed to give opportunity to run them during prolonged wet weather or during the winter. In Europe, many types of dryers have been patented for the drying of peat for various purposes, some of which are manufactured to order, and some are on the market continuously. Of these the rotary types seem to be most in favor as doing the work quickly and with economy. In drying the peat for this, as well as for other uses, it is well to remember that it is not necessary to get rid of all the moisture, but simply to reduce the fiber to the air-dry condition, containing from 15 to 20 per cent of moisture. If reduced lower than this, the cost is greater in proportion and the expense is wasted, since the material immediately takes up from the air sufficient moisture to give it the amount given above. In this country, because of the high cost of labor, most of the work of handling the peat for this as well as other purposes, must be done by machinery, and before attempting to develop the industry and to establish it upon a paying basis, no more profitable step can be taken than to thoroughly study the practice and machinery which have been developed in Germany and other countries of Europe, where the matter has been under investigation and has long passed the experimental stages of development; after which the markets in this country need to be studied, to see whether they will take the manufactured product in quantities which will warrant the erection of a plant. It may be said in passing, that some years ago an attempt was made in New Brunswick, where large deposits of nearly pure Sphagnum are found, to use these for the purposes under discussion, which resulted unsatisfactorily, because of the cost of production of the finished product, and the limited demand in the available markets, which, in this case, could be more cheaply supplied from Europe. The fine residue left after cleaning the peat for coarse litter may be used for fuel or sanitary purposes.

(2) The same kinds of peat which are used for stable litter, may often be used in the barn-yard with excellent results, acting both as a deodorizer and as an absorbent and saving much valuable fertilizing material. For this use the peat should be taken from the upper layers of the beds and should be well dried out before drawing. After the surface vegetation is removed from the bed to be used in this way, it may be plowed with shallow furrows in order to loosen up the fibrous peat, and then, after harrowing, the material may be turned over by a hay tedder, until thoroughly dry. The dry material may then be raked up and stacked, and it will keep dry for a long time, since only the outer layers of the stack will be wet even during prolonged rains, or it may be compressed and baled in a hay press, and stored under cover.

Dry powdery peat is also recommended for use in barn-yards and acts in much the same way as the coarser forms.

Peat as a Disinfectant for Farm Use: In many cases in isolated dwellings, the matter of sewage, cesspools and other receptacles of a similar nature, is a difficult one to handle, because of the cost of proper construction, and often, also, of materials for disinfecting them. The results of neglect are often the pollution of the water supply and many forms of bacterial or germ disease, the breeding of flies and mosquitoes and various other annoyances and positive dangers.

Dry, powdered peat, such as the screenings from cleaned peat fiber, or ordinary fine peat, either slightly charred, or in the ordinary air-dry state, mixed with 1% of powdered copperas (ferrous sulphate), is a very cheap and quite efficient disinfectant and deodorizer for all such places and makes the best material known for earth closets, urinals and vaults, being light in weight, cheap, odorless itself, very absorbent of both liquids and gases, and antiseptic, and is much more lasting in its effects and more easily handled than sand or dry earth, lime or ashes. After such use is made of it, it has high fertilizing value, either used directly or composted. Many efficient forms of peat closets, urinals, etc., are advertised by the European manufacturers of such articles.

Peat as Stock Food: At first thought, this would seem to be an impossible use for peat, but in various parts of Europe, especially in the regions where beet sugar is made, the molasses is fed to stock and sheep, and among other materials which have been used to take up the molasses, are peat powder and cleaned fibrous peat, which give the molasses body and make it possible for it to be eaten readily by the animals to which it is fed. This is not its only function, however, for it has been demonstrated, by actual analyses, that the peat has a certain food value and that part of it is assimilated by the animal eating it, moreover this mixture keeps well and does not ferment so readily as does the molasses alone. While such a mixture is not now known to be in use in this country, there is no reason why in Michigan some of the lighter colored peats should not be tried with success for this purpose, in the vicinity of the beet sugar factories, where the molasses may be had at a nominal cost.

For this purpose, also, it would be possible to use the finer refuse, or peat mull, from cleaning the coarser kinds of peat to make peat fiber and litter, if there was not too much actual dirt of indigestible kinds mixed with it, as would rarely be the case.

Peat as a Deodorizer and Disinfectant in Towns and Cities.

As has been pointed out in the previous section, peat is a good, cheap, and effective deodorizer and disinfectant. In 1880, according to Macfarlane[1] Dr. Ludwig Mappe in Braunschweig, first called the attention of the public to the value of peat litter, or "moss litter," as a deodorizer and absorbent for use in towns and cities, and a gradually increasing use for this material has since grown up. Its use as a public health measure has been adopted in several towns in Germany and in Congleton, Cheshire, England. It has also been used for years in Canada, at Caledonia Springs, to deodorize human refuse. The material is excellent for use in all places such as public urinals, stables, outhouses and slaughterhouses, where easily decomposed, noxious smelling compounds, whether liquid, or partly solid, accumulate to become the source of annoyance, or actual danger to public health. One part by weight of the peat litter will deodorize and dry at least six parts of mixed excreta, giving a perfectly odorless and inoffensive product, which has a relatively high value, as compared with stable manure, when used as a fertilizer for all agricultural crops except those which, like celery, lettuce, and other vegetables eaten raw, for which it should never be used.

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[1] Macfarlane, Th. Bulletin 97, Lab. Inland Rev. Dept., Ottawa, Can., 1904, p. 33.

In Montreal, carefully conducted experiments on a large scale by Dr. Laberge, using moss litter produced in Welland county, Ont., show that 100 pounds of the litter dried and deodorized eight times as much excreta from the ordinary privy pits of that city, rendering it entirely free from odor, so much so that a sample of the product was kept in his office for a considerable time without attracting attention by any odor.[1]

There are many towns in Michigan where sewer systems of the ordinary type are lacking, or are practically impossible, and where the pubic health is continually menaced by existing conditions. In most of these, the general use of peat litter by the people and by the public officials would do away with many of the danger spots, which are now the breeding places of disease germs, flies, and vermin, and from which epidemics either have already originated or may develop at any time. For the use of these towns, local supplies of peat could easily be utilized, the product gathered and compressed under contract by the local health authorities, if no one else could be found to attend to the matter. A short period of compulsory use, would result, in most cases in the voluntary adoption of the method, just as the establishment of a system of sewers often results in the general connection with them, of residences along the lines, although compulsory connection at times has to be enforced.

Use in Hospitals: A form of antiseptic and exceedingly absorbent dressing for wounds made from peat has been prepared and used in Europe, where its absorptive power was found to be greater than that of cotton, and even when saturated with blood, showed no signs of decomposition even when not attended to for several days. Peat dressing was reported to be used by the Japanese surgeons during the Japan-Russian war, but no description of the preparation or use has been found. Certainly however, dried, properly prepared Sphagnum peat, or the dry moss, is a clean, very absorbent material and is said to be nearly or quite sterile, i. e., free from bacteria of any sort. In actual practice, however, since no chances should be taken where wounds are concerned, the material should be thoroughly steamed before use, thus insuring the sterilization. In a cotton producing country, it is probably true that a long time will pass before sterilized absorbent cotton will be superceded by peat dressing. A much more practical, and more valuable use for the coarse kinds of peat litter, properly sorted, for hospitals, is its utilization in the manufacture of mattresses and bedding. Here it has the advantages given above, viz.: it is very absorbent, a deodorizer and disinfectant, is practically sterile and more than all else, for this use, it has the advantage of being cheap, so that it may be renewed often. In addition it may be said, it is light in weight, is springy, if properly cured, and makes a better bed than most of the materials now in use for mattress making. The best type of peat for this purpose would be the superficial layers of either sedge or moss peat, the latter probably being the kind to be preferred. Where the material has been tried in Europe it is reported to be exceedingly satisfactory, and it is to be hoped that wherever beds are needed that have to be changed frequently, this material will be given a fair and impartial trial.

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[1] Macfarlane op. cit. p. 35.

Destructive Distillation of Peat.

Like all other forms of fuel, which are of vegetable origin, peat is capable of being decomposed into a series of simpler chemical compounds when heated in closed receptacles away from the air. Wood and bituminous coal are treated in this way on a very extensive scale, the main products sought being charcoal, from the wood, and coke, or, in certain cases, gas for illuminating and heating, or power, from the coal. The general process, known as destructive distillation, consists of heating the substances of organic origin in heaps or mounds, covered with earth, or some form of vessel or structure, which is so arranged that air is entirely excluded, or is allowed to enter only to a very limited extent, while means of exit are provided for the gaseous products of the decomposition brought about by the heat, either directly to the outside air or through tubes, so that the escaping vapors may be cooled, condensed and saved, since some of them have commercial value. The familiar charcoal kiln, a dome-shaped brick structure in which wood is stacked and a fire started in the stacks, to be controlled by carefully regulated draught openings at the bottom, while the gases escape into the air at the top, is a crude form of apparatus in which wood is converted into charcoal, the gases and other volatile matters being allowed to go to waste, except the heavy wood tar, which usually condenses on the inside of the kiln. More elaborately and scientifically built charcoal kilns are constructed of iron, and are heated from the outside, the gases liberated being conducted through properly built flues, so that they may be saved by condensation and used. If the gases from wood distillation are saved, the lightest ones cannot readily be condensed into liquids, but as gases they take fire readily and burn with great heat, and may be used for illumination, heating or for generating power in gas engines. In good practice, in wood and coal distillation, these gases are used either to heat the kilns, or retorts, or are burned under boilers to generate steam for engines used about the plant, as they are in the best processes in coking peat abroad. With these gases comes a series of substances which are liquids at ordinary temperatures, chief of which, are water, various organic acids, wood alcohol, creosote and tar. In the same way that wood yields charcoal and these other substances, for which thousands of cords of wood involving the stripping of hundreds of acres of woodlands annually in Michigan alone, peat may be used as a source of practically the same series, and, in many cases, to quite as good advantage. This is by far the most rational and scientific way of preparing peat for use as fuel when it is to be transported for some distance from the bog, especially if the by-products are saved.

Peat Coke and By-Products: The coke made from peat is jet black, firm and hard, has the fibrous or columnar structure of coke made from coal, and like it, rings slightly when struck. It is as free from sulphur and phosphorus as charcoal, all of the sulphur being contained in the ash as sulphates and has a thermal value of about 7,000 units (from 6,776 to 7,800 calories). With less prolonged heating, substances less hard and firm, similar to charcoal in efficiency, are obtained by the destructive distillation of peat.

In Germany, where peat coke is said to have been used in the smelting works at Freyburg as early as 1360, and where many unsuccessful attempts have been made since that time to develop a commercially successful product, the inventions of Ziegler and others have carried the process of coking peat beyond the experimental stages, and it is now reported by careful students of the subject, to be manufactured on a paying basis; such of the coke as is on the market sells readily at from $9.50 to $12.00 per ton, and is used for copper refining, smelting foundry iron and for other metal working processes, but the industry is still in too undeveloped a condition to furnish the coke for use in blast furnaces, although it is in every way as desirable for this purpose as the best wood charcoal.

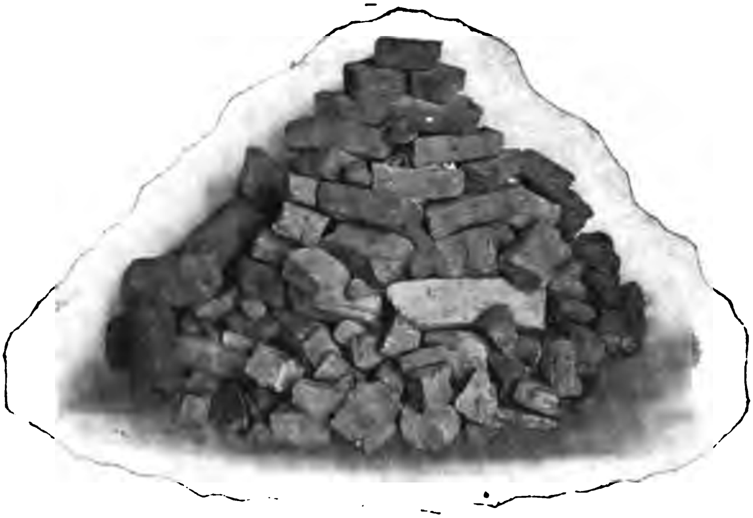
A sample of peat coke from Germany, made by the Ziegler process, was recently examined by the writer. It was jet black in color, as hard and as firm as a good grade of hardwood charcoal, or possibly even firmer than this, and showed the character of the peat from which it was made so well that it was possible to determine this to be of coarse texture, chiefly remains of shrubby plants. Apparently the peat had not been ground or in any way treated, except to cut it from the deposit and dry it, before it was coked. The material appeared to have been originally like that of the uppermost layers of peat in thousands of acres of Michigan swamps of a grade most of which would have to be rejected in the manufacture of briquetted peat fuel, and it would appear that a more compact and finer grained peat, coked to the same degree as this sample, would yield even a better grade of coke.

The makers of this peat coke report that it stands the pressure exerted in blast furnaces better than charcoal, not crushing in an 80-foot blast furnace, and equally as well as coke produced from coal. Whether this statement applies to the charcoal produced in Europe from the softer woods or to that made in this country, as in Michigan, where the sound and largest logs of the finest birch and maple timber are still cut up and converted into charcoal, does not appear. The cost of production is less than that of charcoal and the actual cost is given in another place (page 300).

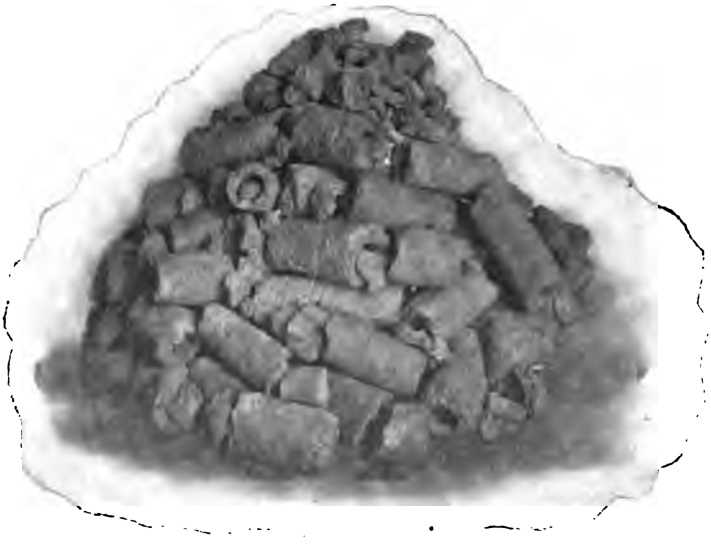
If such fuel can be made from an inferior grade of peat, at as low a cost as quoted, there would seem to be no good reason why the remaining forest lands of the state, and especially of the Northern Peninsula, should be stripped to make charcoal for use in smelting iron, while quite as near at hand to the iron mines as the forests are large deposits of good peat entirely unutilized. Such utilization of peat would leave the vast quantities of timber now converted into charcoal, to serve as the basis for other industries.

It may also be used anywhere and for any purpose where an efficient, smokeless fuel is required, or in industries where such fuel is necessary In domestic use it may be used in base-burner heating stoves, kitchen stoves and in other places where charcoal is now used, but will probably never successfully compete with anthracite for general use.

Besides the coke, there are obtained as secondary products, in this



PEAT FUEL, BROKEN.



PEAT COKE, BROKEN.

method of preparing peat, gas, which is used to carry on the process of coking after this is once started, tar, and lighter liquors which yield various products on proper treatment, and which nearly if not quite, pay for the cost of the whole operation.

The amount of coke yielded from a given weight of peat ranges from 30% to 45%, in round numbers about 1/3, but varying with the compactness of the original material and the length and intensity of heating, the highest yield being obtained, and the best coke, from artificially compacted peat. If heated a shorter time, peat charcoal, much less compact and more friable, is obtained.

According to German figures and prices, a metric ton, nearly equaling the long ton of 2,240 pounds, of dried peat, costing for all charges of digging, handling, drying and delivery to the kiln, $1.19, yields the following returns:

Substances.	Amount.	Value (U. S. currency).
Peat coke	777.6 lbs.	$3.75
Tar	88.2	.52
Wood alcohol	13.2	1.00
Lime acetate	13.2	.17
Ammonium sulphate	8.8	.21
	Total	$5.65

besides gas in excess of the amount required to dry and coke the peat, which may be estimated to be worth for the purposes for which it is used, at least 25% of the value of the coke. No other fuel than this gas is used in drying and coking the peat after the process is started.

Another writer gives as the results of factory tests the products from one ton of peat, as follows:

Peat coke	700 lbs.	
Tar water	800	
Tar	80	
Gas	420	(6,650 cu. ft.)
The tar water yielded:		
Acetic acid	12 lbs.	
Wood alcohol	12	
Ammonium sulphate	8	

The Ziegler process, which seems to be the most successful of those in use in the peat-producing parts of Germany and Russia, is continuous, and, as pointed out below, self-sustaining.

The facts regarding this process are largely compiled from data most kindly furnished by Dr. Otto Zwingenberger, the representative in America of the company controlling the Ziegler patents and manufacturing the machinery for making coke from peat by this method.

The first plant using the process was erected in Oldenburg in 1897, and after careful examination by an expert employed for the purpose by the Prussian State Department of Trade, on his recommendation, this process was adopted for the utilization of extensive peat bogs owned by the Prussian government.

A second plant was built in 1901 in Redkino, for the Russian government. This plant runs 8 furnaces, each manufacturing 5,000 tons of peat coke per year.

The latest plant to be built is that at Benerberg, South Bavaria where the South Bavarian Coke Works and Manufactory of Chemical Products Joint Stock Company of Munich, which now controls the Ziegler patents, has its headquarters. This new plant has four furnaces and is equipped for recovering the by-products from the tar and tar water saved from the distillation of the peat, and went into operation in 1906. The process used by these establishments consists in carbonizing the dried "machine" or compressed peat in closed retorts heated by burning under them the gases liberated from the peat by the heat. The peat is cut from the bogs, compacted, and molded into square blocks by ordinary peat machines coming out as "machine-peat." It has, at this stage, from 80% to 90% of moisture and is allowed to dry in the open air until it contains only about 50% or 60%. After this preliminary drying, it is removed to drying chambers, heated by the waste heat from the retorts and burning gases from the furnaces, and is passed slowly through these and comes out with from 20% to 25% of water. From these dryers it is carried to the top of the iron retorts of special form by endless belts, and at regular times is placed in these air-tight, vertical receptacles. In this thorough drying to the point of crispness, at no expense for fuel, so that it is rapidly carbonized when placed in the retorts, seems to lie the chief secret of success in the recent process as compared with older ones, for when the peat was placed wet in the kilns, the water was only driven off with great waste of time, heat, and of fuel, so great that there was no margin of profit in the operation. The economy of the Ziegler method of drying the peat, first in the air, and later by waste heat, generated by the combustion of what would be otherwise waste gases, is apparent when compared with processes which used separate drying chambers, heated independently by the use of costly fuel and allowed the combustible gases and other valuable, volatile, but condensible vapors, from the retorts to escape into the air, and be wasted.

The condensible gases are not wasted by this system, but are conducted through proper cooling apparatus and then redistilled by the use of excess of heat, generated by the process of coking, into a number of commercially valuable products.

These vary in quantity, according to the thoroughness of the coking, and the quality of the peat, that with high ash content, giving a smaller per cent of volatile matter than that with low; the coking is carried farther with peats with a small per cent of ash than with those with a large per cent, the resulting products being sold as No. 1 peat coke—that most completely coked, and No. 2 peat coke or "half coke."

No. 1 peat coke is somewhat harder than the half coke, and the latter burns somewhat more freely and with a more noticeable flame, and it is not so well adapted to metallurgical processes as No. 1 peat coke. The peats with high per cent of ash, since this is mineral matter and does not volatilize when heated, give a larger per cent of coke, which, however, does not give good heating results, as the ash will not burn.

The proportionate amounts of the various products obtained by coking

100 parts of air-dry, 20% to 25% moisture, machine-peat, are shown in the following table:

	No. 1 Peat coke.	No. 2 Peat coke.
Peat coke	33.0 per cent.	45.0–50.0 per cent.
Tar	4.5	2.0
Tar water	40.5	38.0
Gases	22.0	15.0

Carrying the processes farther to make by-products by redistillation;

No. 1 Peat coke	33.0 per cent is untreated.		
Tar	4.5 " " properly treated yields	2.0 per cent	of light oil.[1]
		0.7 " "	heavy oil.[2]
		0.3 " "	Paraffin.
		1.3 " "	Phenolates.
Tar water	40.5 per cent will give	0.2 " "	Asphaltum.
		0.34 " "	Wood alcohol.
		0.31 " "	Ammonium. Sulphate
		0.50 " "	Acetate of Lime.

Gases....22.0 per cent not condensible, but burned under boilers and dryers.

The per cents of ash and of tar obtained vary according to the quality of the peat used. The coke may be increased in quality by using briquetted peat. This also gives the coke somewhat greater density.

Products from the tar, and the tar itself, are of considerable value as preservatives of wood used for railroad ties, posts, poles, and timbers for all structural purposes, both when applied as paints externally, or when forced into the wood as impregnating substances. The hydrocarbons of the oils are of the aromatic series, and from them a series of useful chemical compounds can be obtained.

In regard to the cost of producing peat coke, Dr. Zwingenberger says: "Its price is cheaper than that of charcoal; by saving the by-products, the cost of one ton of peat coke is about $2.00 to $2.15 in running the smallest type of Ziegler plant, containing four ovens, taking in consideration the high wages paid in America, and including depreciation, etc. In a larger plant of about 20 ovens, the value of the by-products will nearly pay all the expenses and give the coke free."

Peat coke being cooled in closed receptacles to prevent its taking fire, does not contain water, since after cooling it is not absorbent, while charcoal sometimes takes up considerable water.

In Germany, peat coke is used successfully in several places, among which may be mentioned the Krupp-Gruson Works, where it is used in the form of a powder for hardening armor plates, and the Bleymueller Works at Bleyberg, near Schmalkalden, in a blast furnace. Siemens and Halske, Berlin, have found it an excellent raw material for the production of a high grade of calcium carbide.

In Russia, as noted elsewhere, peat coke is being used on the government railways as fuel for locomotives.

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[1] Sp. Gr. 0.835. May be used for lighting.
[2] Sp. Gr. 0.838. May be used for lubricating oil.

The capacity of each furnace, or retort, as at first constructed, was about 11,668 pounds of coke, 13,333 pounds of tar water, 1,333 pounds of tar, and 7,000 pounds of gas (110,850 cu. ft.) from 33,333 pounds of air-dry peat (20% to 25% of moisture) in 24 hours. At the Imperial Russian Krons Peat Factory, at Redkino, each of the eight retorts cokes from 24 to 30 tons of machine-peat having 25% of water in 24 hours, a larger output than the above quoted figures show.

The cost of a four-oven plant, for making peat coke by this process, with all necessary machinery for cutting, drying and handling the peat, and the apparatus for making the by-products from the waste liquors, was given in 1903 to be $95,200. Such a plant was estimated to handle 15,000 tons of dry peat per year, from which products could be made, which would sell at the wholesale market prices of that time, in Germany, for about $117,500, nearly one-half of which, after deducting all expenses for the cost of peat, handling, labor and wear of plant, repairs, etc., should be profit.

Another set of figures obtained from Hon. J. M. Longyear, who had them from J. J. Hill, gives the following as the cost of a peat coking plant, German process:

Two peat coke ovens, capacity 30 tons air-dry peat, each yielding 10 tons of No. 1 coke or 13.5 tons of No. 2 coke per (24 hours) day	$20,000
Drying and other machinery	8,000
Apparatus for distilling tar water	7,000
Total	$35,000

A plant of 10 ovens, with a capacity of about 100 tons of No. 1 coke per day can be had for $175,000, and the estimated cost of a second plant after the first is constructed is 25% less than this.

So far as known there are no peat coke plants in this country which are producing the material in such quantities that it is sold in the open market.

Peat coke was also made in Norway for several years by the use of electrically heated retorts, the electricity being generated by water power, the plant using the Jebsen process, which produces a dense, very compact coke, showing the structure of the peat, having a specific gravity of 0.3 in broken condition. Its heating value is about that reported for that made by the Ziegler process. It is reported that it burns well, and gives but little soot and ash, and clinker is small in quantity and does not clog the fire as does that of ordinary coal and of lignite.

This process involves the partial drying and pressing the peat into blocks 30 inches long, by 3 inches square on the ends. The blocks are turned out at the rate of 2,500 per hour and loaded on specially designed carriages with shelves, which are then run into the cool end of a drying tunnel, which is heated by the waste gases from the retorts. At the entrance end, the temperature is about 50° C., while at the exit end, it is from 90° to 100° C., the air being driven through the tunnels by electric fans. From the drying tunnel, the peat is taken to the retorts, which are vertical and are about 6 feet high by 3 feet in diameter, each with a cover above, and a discharging hole below, and each is also provided with pipes for the escape of the gas and with a pressure gauge. After charging with the dry blocks, the top cover is clamped down and the current turned on and the peat is carbonized. When the heating is completed, the retort is allowed to cool to 130° C., after which the coke is discharged directly into cars on tracks below the retorts. The average yield of air-dried peat by this process was given as:

Peat coke	33%
Tar	4
Tar water	40
Gas	23

The coke was said to find ready sale in near-by towns, and the plant had been running three years when described in 1902, but was closed later for lack of financial support.

Analyses of peat coke made by the Jebsen process, reported by the Royal Norwegian High School in Christiania gave the following as the average composition:

Carbon	76.91%
Hydrogen	4.64
Oxygen	8.15
Nitrogen	1.78
Sulphur	0.70
Ash	3.00
Moisture	4.82
	100.00%

Another electric process has been devised in England, but so far as known, it had not passed beyond the experimental stages.

Peat Gas: Because of the undecomposed condition of the vegetable matter of peat and the large amount of volatile matter which it contains, it is not remarkable that it should have been used often, in an experimental way, as a source of gas for various purposes, but in northern Europe, especially in Sweden, the use of the gas for heating and lighting has gone beyond the experimental stages and has reached the stage of commercial success.

In considering the methods of making peat coke just described, the value of the gases developed in the destructive distillation of the peat has been dwelt upon at length. This gas is reported by those who have used it to be a better illuminant than coal gas, to be more easily produced, with simpler apparatus, to be more easily purified than coal gas, and that the yield per ton of the dried material is greater. This last statement is probably true, because of the less complete decomposition of the peat as compared with coal, which makes it relatively high in gases. On the other hand it must be remembered that the peat, with 90% of water, has to be dried by some process before gas can be made from it, and that it is only by using the least expensive process to accomplish this that peat gas can be made economically upon a commercial basis.

The quantity of gas obtained in Sweden from a metric ton (2,204 lbs.) of peat having 8.6%, or more, of ash and high hydroscopic moisture content is given by Dal as 2,520 cu. meters or 89,000 cu. ft. This gas, however, is more than half its volume Nitrogen, as shown by the accompanying analysis:

	Per cent of volume.
CO_2	6.9
CO	26.
C_2H_4	0.5
CH_4	4.4
H	8.5
N	53.7

Better grades of peat yield a larger volume of fuel gases. The amount of gas yielded by English cannel coals per ton, is indicated in the following table:

Newcastle cannel	9,883 cu. ft.
Wigan cannel	10,850
Boghead cannel	13,334

while a ton of peat by the Ziegler process only gives 6,650 cu. ft., which, considering that the peat has 20 to 25% of moisture at the start and costs, at the bog, a little less than a third as much as the coal, really gives the peat the advantage, especially since the peat coke will command a much higher price than gas coke, on account of its freedom from sulphur and other objectionable matter.

The great efficiency of gas engines of the explosive types, the rapid increase in size and the very material increase in the use of these, in many places where steam engines have, until recently, held the entire field, opens up an important field for the use of easily ignited gases; this has resulted in a demand for cheap and efficient gas generating machines, which will furnish gas at a lower price than it is furnished by the large private or public companies which manufacture coal gas, or which can be used where no public plants are in use. This demand has been met by a large number of gas generators of small size, designed to be used in connection with gas engines, to utilize poor grades of coal, some of which are very successful, and it would seem that special forms of these could be developed, in which the gas could be generated from air-dried peat, and thus work up an important field of use for this fuel. By those who have experimented with it in this direction, peat gas is said to be particularly adapted for use in gas engines, and the only phases of development lacking are the proper forms of generator for making the gas and an assured and constant supply of prepared peat which consumers can get as needed.

In still another way may peat gas be utilized on a large scale, as suggested in another place. That is by building large gas generating plants, with proper equipment for utilizing all gaseous by-products, at the margin of large peat bogs and piping the gas to centers of consumption. This would reduce the cost of manufacture, by doing away with the transportation charges on the crude fuel, and would be no more difficult to bring about than piping oil or natural gas long distances. That peat gas is being considered as a possible cheap fuel and is likely to be utilized before long, is indicated by the recent (June, 1906) newspaper notice of a project for the establishment of a plant for producing the gas near Ogdensburg, N. Y., and utilizing it in the manufacture of steel. In developing this, as well as other phases of utilization of peat, a thorough investigation of European experiments and established plants is recommended. It is worth noting here that there are large quantities of peat near the Lake Superior iron mines, which might be utilized in the production of charcoal iron and for furnishing power either steam, compressed air, gas or electric for developing and operating the mines.

Paper Pulp, Paper and Cardboard.

One of the more recent uses to which certain grades of peat have been put, is the manufacture of paper pulp and various grades of paper. This is of interest in this region because of the establishment of a plant in Michigan, near Capac, for the purpose of making peat into paper, which, in this case, is reported to be used for building purposes.

The chief advantage in the use of peat for paper stock is its cheapness of material, particularly as the prices of other sorts of material and especially wood pulp are constantly increasing, as the wood supply becomes more and more depleted. In one of the processes for making paper from peat, the Zschoerner process, the peat is placed in a disintegrator, where it is treated with alkalies in dilute solution and at low temperature, but high pressure, until some of the vegetable and earthy matters are extracted from the fibrous material. This fiber is then oxidized, bleached and washed to further clean it, and again subjected to cold, dilute alkali solution under high pressure to get rid of the remainder of the soluble mineral matter, after which it is thoroughly washed, when it is ready for use. This bleached material may be used by itself, or mixed with other paper stock to make nearly any grade of paper in ordinary use, as the fiber thus obtained is strong and durable. In making the coarser grades of paper and pulp board, less care is taken to cleanse the fiber of all coloring and foreign matter.

✓ The type of peat best adapted to this use is undoubtedly that made by grasses and sedges, since these plants furnish the most fibrous material in stems, leaves and root-stocks. In prospecting peat deposits for this use, care should be taken to find the depth and amount of fibrous layers and to avoid the filled lake basins, unless of large extent, as usually these have only a shallow, surface layer of material suitable for the purpose, while thinner, built-up deposits, may have practically the entire depth of more or less coarse, poorly decomposed, fibrous peat. These will be found in shallow basins and on terraces, and may, at present, be covered by tree or shrubby growth, or by moss. Moss peat, despite many statements to the contrary, contains no strong fibers whatever, except those produced by other plants, such as the sedges, which may grow with the moss as associates.

There were already in operation, in 1899, in Europe, several factories which produced large quantities of all kinds of paper, with peat as the source of most of the fiber, and these were reported as paying institutions. On the other hand, there are serious drawbacks to the economical use of peat in paper making, which may be summed up as follows: It is difficult to get rid of the dirt and waste; the peat is uneven in structure and in texture and often lacks sufficient of the stronger fibers, so that much other material has to be mixed with the peat stock to make paper sufficiently strong even for wrapping paper, so that it is reported that there is little peat paper on the European markets which is more than 75% peat; the peat pulp cannot be bleached to whiteness, so that only brown papers can be made, except in rare instances, hence the principal product of the European industry has been wrapping paper.

Pasteboard made of 40% of peat fiber and 60% of wood shavings is a standard product, both in Germany and in Sweden, and is said to be cheaper, lighter, stronger, and better than pasteboard made in the ordinary way.

Aside from the factories reported in Germany peat paper has been made in England, Ireland and Austria, as well as in the northern European countries, but with what financial success is not reported.

The plant of the American Peat and Fuel Company at Capac in this state, was leased in 1905 for two years, and has since been sold, to the Pilgrim Paper Company of New York, organized for the purpose of manufacturing and selling card-board, bill-board, feather-board, paper, and other products from peat under Austrian patents. The materials in the extensive bog owned by the company, had been carefully tested in the home factory of the company's process at Admont, Austria, and later at Capac, and produced highly satisfactory results, and the company is convinced that the processes have passed the experimental stage, and are confident of the success of their enterprise, for which the Capac peat bog is peculiarly adapted, having been built up, by successive elevation of water level, from the bottom, and hence has much coarse material at various depths.

Similar to a heavy paper, is the material known as "Heloxyle," made by compressing and hardening peat fiber, by a special process, into sheets, tiles and blocks for various building purposes. The sheets are used for lining walls, floors and other parts of buildings, or as flooring. The material is about as light and firm as good cork and is as impervious to moisture, as well as a good non-conductor of sound, heat, and vibration; when impregnated with some mineral substances, it is nearly fire-proof, all of which properties make it very desirable for use in dwellings and buildings, where protection is desired against noise and jar. It is one of the cheapest of all building materials in Germany and is easily nailed or glued, takes paint well, is light, clean and easy to handle, and hence is very desirable as a structural material. Other types of sheathing and builders' paper are discussed below.

Woven Fabrics from Peat.

By a course of treatment which separates and cleanses the fibrous parts of peat, and renders them pliable, they have been made into fabrics of various kinds, so that coats, hats, carpets, rugs, mattings and blankets have been manufactured from them and have proven quite durable. The most successful use of these fabrics has been in the form of blankets and other coverings for horses and cattle and for this use they are said to excel in warmth, durability, absorbent power and cleanliness.

Packing Material.

Peat litter has long been used, when properly cleaned, as packing material in shipping various breakable articles and those which perish easily, such as bulbs, fruit and living plants, by freight. For these purposes, the upper layers of moss peat are most desirable, and considerable quantities of this material are used yearly by florists and nurserymen, where they can readily get it. No industry has been developed, but a small business to supply the demand of the florists and nursery-men of the state and surrounding region, might be built up by someone to whom a moss covered bog of sufficient extent was accessible. The moss would best be compressed and baled for this purpose. Peat might also be used to pack fruits and vegetables to keep them fresh for winter use, as this material has many advantages over sand, the material generally used for the purpose. It is also suggested that it would be a desirable substance in which to pack eggs to preserve them.

Roofing and Sheathing Papers.

As has been mentioned, the extensive peat bog near Capac has been sold to a company which proposes to manufacture, among other products, a kind of builders' paper from the peat. The coarse-fibered peat is well adapted to this use, as well as the making of such material as "Heloxyle" mentioned above as a valuable building material. Coarse, felted material should also be easily made from the cleansed fiber, which would be an excellent non-conductor of heat for sheathing buildings. The paper thus prepared could also be rendered waterproof by soaking it in tar obtained by distillation of peat. The coarser, more fibrous parts of moss peat could be used, as is the marine plant known as "Eel Grass," which is spread in a thin layer between sheets of heavy paper and held in place by stitching through the paper. This material is used in the better classes of buildings, for sheathing paper.

Non-Conducting Packing Material.

Still another use has been made of both the fibrous peats and the finer grained, powdery types, as non-conducting filling or packing. This material is an excellent non-conductor of heat and sound, and has been used as such in Europe. The moss types make light, inodorous, sanitary and effective packing for use between the walls in refrigerators, ice houses, for packing ice, and to put between the walls of dwelling houses, and between floors and partitions to deaden sound. The same material would also be exceptionally valuable in the construction of the so-called caloric cookers. If used in connection with some mineral substances, which would reduce its inflammability, it would make very desirable felted covering for steam pipes, and could in any case be used to protect those buried in the ground from loss of heat, and also water pipes to keep them from freezing, for which use the cheapness and the durability as well as the porosity of the material would make it especially desirable.

Paving and Building Blocks.

Blocks of material for special uses made from peat, by special processes, besides the one mentioned as "Heloxyle," have been made in larger or smaller quantities from time to time, among which may be mentioned imitation terra cotta building material and paving blocks. The latter were as firm and hard as wood and were impregnated and covered with tar made also from peat. If a proper binding material could be found, there seems no reason why a very serviceable and durable, noiseless paving block for residence streets could not be made from some of the more compact peats, and one that would be cheap as well.

Peat as a Source of Electrical Energy.

As shown in another chapter it has been proposed by a European engineer to establish near, or at, large peat bogs, electric power plants, at which the peat can be used for fuel in the air dry condition, without briquetting, thus saving not only the cost of transporting the fuel, but other costs as well. The power thus generated can be transported considerable distances without great loss, as is well known, and if the plan were adopted generally would result in many bogs being utilized, which cannot now be considered, since they are remote from means of transportation. No such plan as the one proposed has yet been put in operation, but, as indicated elsewhere, it seems worth trying in certain parts of Michigan, where large areas of peat are within reaching distance for the transmission of electricity, of good sized towns and cities.

Peat Dye.

It is well known that water flowing from peat bogs is much browner than that which flows only through or over mineral soil, and that such water gives a well marked and quite durable stain to white substances coming into contact with it. Advantage has been taken of this fact to extract the coloring matter from peat, and by proper treatment, a rich brown dye has been obtained which is reported to be very pleasing and exceptionally durable and unchanging.

The Use of Peat in the Intensive Production of Nitrates.

In the Experiment Station Record, XVIII, 5, (Jan., 1907) is an abstract of a recent paper by Muntz and Laine, published in Compt. Rend. Acad. Sci., in which experiments are reported which promise to give new and added importance to the peat deposits of the world, since the authors show that these deposits may be made factors in the production of nitrates. The nitrates are among the most expensive and most important of the constituents of fertilizers, being of limited natural occurrence, and having very important commercial uses aside from the demand for agricultural purposes.

The experiments reported show that "when a 0.75 per cent solution of Ammonium sulphate is passed over a peat bed impregnated with nitrifying organisms, it becomes charged with nitrates to the extent of 0.82 per cent. This can be increased to 4.17 per cent by adding a further quantity of Ammonium sulphate to the solution and again subjecting it to the nitrifying action, the operation being repeated 5 times. The most suitable temperature for the reaction is 30° C. (86° F.), and the fuel necessary for maintaining this temperature is afforded by the air-dried peat. Further the nitrogen contained in the peat, which amounts to 2 to 3 per cent, can be obtained in the form of Ammonia to the extent of 1.79 to 1.612 per cent by distilling the peat in superheated steam, the other products of the distillation (hydro-carbons, water-gas, tar, etc.), forming the fuel required for the operation.

"Péat, therefore, is singularly well adapted for the intensive production of nitrates, since it forms an excellent medium for the growth of the organisms, supplies the fuels necessary for the various operations, and finally supplies the ammonia required for the production of nitrates."

The immense consumption of chemical fertilizers in this state, the very considerable manufacture of these in Michigan from imported nitrates and the great extent of the peat deposits throughout the state, suggest the importance of investigating this method of intensive production of nitrates from peat to determine whether it is not applicable, upon a commercial basis, to American conditions. The great development of chemical manufacture based on the salt deposits of Michigan, in the not distant future, may be equaled by a similar development based upon the peat deposits, to the great advantage of all agricultural interests, of the chemical manufacturing industry, and of the promoters as well.

THE USE OF PEAT AS FUEL.

Historical: The use of peat as fuel in Germany goes back beyond the historical period into the time of the semi-savage stage of the early tribes, and Pliny, the Roman naturalist, tells us that the Teutons on the borders of the North Sea dried and burned "mud," or, as we would call it now, peat. In Ireland, Great Britain, Russia, Scandinavia, parts of France and the Netherlands, there has not been a time within the historical period, when the use of peat for fuel has not been a general practice among the common people, who still cut it from the bog in the form of long rough bricks or "sods," drain and dry it on the surface of the bog in the sun and wind and stack it, much as the American farmer piles his cut wood.

In Ireland and parts of Germany and Holland the use of peat is well nigh universal among the poorer people, and in other countries of Europe it is extensively used for cooking and other domestic purposes. This is due to several causes, among which the scarcity and high prices of wood and coal, and the great abundance of peat bogs and the large aggregate area covered by them in the countries of Northern Europe, Germany alone having an area of about 11,000 square miles of peat moors, while Great Britain has more than 3,000,000 acres and Ireland an equal extent, or about one-seventh of its entire area covered by bogs. The most widespread use for domestic purposes was probably in the 18th century, after the forests were so depleted, that wood was no longer easily obtainable by the common people, and before coal had come into use.

While this general use of peat by the people for domestic purposes has gone on century after century, there was little attempt to increase its efficiency as fuel, or to improve the methods of gathering it, except some simple attempts at compacting the coarser types by kneading with the feet, grinding in small mills, etc., until within a hundred years or so when various forms of machinery were introduced to assist in cutting the peat and getting it out from the bogs more quickly and less laboriously than by cutting it out by hand with a narrow spade or slane, as it is called, and which is still the most common and perhaps the most efficient tool for the purpose.

Much later, after the need for cheap and abundant fuel for use in generating steam for manufacturing purposes began to be felt, as the prices of wood and coal advanced, machines began to be built in Germany and other parts of Europe where peat was abundant, for the purposes of increasing the output, of reducing the bulk of the finished product, and at the same time of making it more clean to handle, more easy to transport and more efficient as fuel.

A pioneer in the invention of machinery and processes for making compressed peat in Northern Europe, seems to have been Mr. C. Schlickeysen of Rixdorf near Berlin. His first two machines were of vertical construction and were built in 1859, for a steam peat-compressing plant near Riga, Russia, where they worked satisfactorily for many years, turning out daily about 80,000 pieces of wet, compressed peat, which, after drying, were used as smokeless fuel in a large cloth factory at that place. Since that time, many improvements have been made by this and other manufacturers, both in the types of machinery and methods of work, to try to improve and cheapen the product, and to substitute automatic machines for hand labor, until a very satisfactory product in the form of compressed peat blocks and efficient machines for making them, are the results.

A much more recent development and one which seems to be considered by all experts in the question of fuel, perhaps the most important advance yet made in the utilization of peat, as it is the most scientific and theoretically correct, is the working out of good processes for coking peat and converting it into a compact, hard and very efficient and desirable fuel. This kind of process for the purpose has been sought for many years and seems now to have been found, as is pointed out in another place (p. 301) and the matter needs no further elaboration here.

Another recently used method of increasing the efficiency of peat for fuel, has been brought about by the development of machinery for converting other fuels, such as coal slack and other waste of coal mines, lignite, etc., into briquettes. The process consists of compressing the fuel, either with or without a binding material, in specially built presses, capable of exerting great pressure, which shape it into cylindrical, rounded or prismatic briquettes of great firmness and hardness. In some of these processes the peat is mixed with other combustibles, in others, it is briquetted without mixture.

Parallel with the development of these processes in Germany, have gone similar ones in England, Russia, Norway, Sweden, Austria and the Netherlands, but Germany has led the way, and it is there that the most modern and scientific methods and machinery for the manufacture of peat into efficient fuel have been worked out. In fact, there has been much labor and a great amount of capital used up in various unsuccessful processes of handling peat in Germany, and no better step could be taken by the would-be inventor of new and especially desirable processes of converting peat into first rate, cheap fuel, than to make a thorough study of the history of German inventions and experiments in this direction, for it would doubtless save him much time and trouble as well as much money and disappointment.

Use in America: In America, with its great stores of fuel, in the form of wood, and the various types of coal, widely distributed, cheap and abundant, the history of the use of peat is very brief. It was used in parts of New England by early settlers from peat-using stocks, and in the region of Cape Cod and the adjacent islands in Massachusetts, where the original forests were poor and soon destroyed, the use of peat, taken from the numerous bogs of the region, has, according to Shaler[1] been general and continues until the present time. In other parts of New England, its use was discontinued years ago. In the latter part of the 19th century some peat fuel was manufactured at Lexington, Mass., by T. H. Leavitt, but no general use of it has been made in any part of the country, except this, so far as is known, and it was not until the great coal miners' strike of the winter of 1902-03 created a widespread interest in the possibility of utilizing the extensive deposits of various kinds of peat known to exist in the northern parts of the United States, that the public took much notice of it.

Use in Canada: In Canada, the history is slightly different, though similar. There, the deposits are more extensive, than in most parts of the United States, are easily accessible and the land was settled from the more northern parts of Europe, and especially from Scotland, Ireland and Germany, by people who were used to gathering and using peat for fuel. These facts, taken in connection with remoteness from coal supplies, undoubtedly led to a more extensive and earlier use of peat for fuel than in this country, so that in the early sixties, there was a small output of machine-made peat, and a little later, carbonized pressed peat, was placed on the market and tested by manufacturers and railroads. This was followed by a slow development of briquetting machinery, until several plants were established to make peat briquettes, none of which were successful in getting a good product from the process used, that of air drying, grinding and pressing the peat, and after a season or two of attempts, were abandoned. The next series of attempts were made in the direction of pressing the peat after it had been dried by artificial heat, and in 1902 several establishments in Ontario were operating, and with more or less success, were supplying local markets with briquettes made by modifications of this process. The whole development, including descriptions of bogs, processes and machinery is fully described in Bulletin No. 5, of the Ontario Bureau of Mines, and in a later report by the same bureau.[2]

Use in Michigan: In Michigan, since it was, to a large extent settled as was Canada, by people from the countries of Northern Europe, it is probable that there was some use of peat by individuals, especially in the German and Hollander settlements, but the great amount of wood, and its cheapness for fuel, together with the immense quantities of waste mill wood, and drift, or flood wood from the streams on which lumbering, or river driving operations, were being conducted, in the earlier days, and later, the development of the Michigan coal fields, and the close proximity to those of Ohio, all tended to make the use of peat unnecessary, and it was only a short time ago, that the possibilities of utilizing the great areas of peat in the state, attracted general attention. The past five years, however, have seen a marked change in the attitude of capitalists, owners of bogs and the citizens of the state in this matter and a widespread interest, due partly to the rising price of wood and coal, and partly to the constant discussion of the value of peat fuel in the public prints, as well as the effects of the coal famine already referred to, has been aroused and there are few of the citizens of the state who would not now be glad of the opportunity to test the new fuel, if it could be had. Within the period named, there has been an attempt on the part of capitalists to meet this demand for peat fuel and a considerable number of plants have been built in the various parts of the Southern Peninsula and have put out small quantities of finished product, which have found a ready market, and at present writing it appears possible that before long a flourishing industry based upon the utilization of this great natural resource of stored fuel may be built up. Michigan has abundant and good peat deposits, and all that is needed to make them useful is honest, intelligent, carefully planned exploitation.

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[1] Shaler, N. S. Peat Deposits. 16th Ann. Rep., U. S. G. S., Part IV, 1894-5, p. 306.
[2] Report of the Bureau of Mines, 1903, Toronto, Ont., 1903.

Descriptive.

Because of its diversified origin and the very different conditions to which individual deposits have been subjected, peat is entirely lacking in uniformity of structure, is of very unequal fuel value, and varies greatly in texture and color, not only in different bogs, but in parts of the same bog. These peculiarities are discussed at length elsewhere and are due to differences in the age of the deposits, in the form of basin in which they lie, the kinds of impurities present, the amount of oxidation and decomposition, the kind of plants from which the peat is formed, and other more or less important factors.

The chief kinds, as discussed by most writers, are given as those which are light brown in color, coarse in texture, and low in specific gravity; those which are dark brown in color, dense and fine grained in texture and comparatively heavy; and those which are intermediate in characters. To these should be added the light colored and very fine grained types, which have been described as formed by the algæ in the bogs of Northern Michigan (p. 247) and there are all sorts of intergradations between these various forms. In Michigan, in the deposits of the lake basin type, it is not infrequent to have the light colored, coarse type, end abruptly, and pass without gradations into the dark colored, compact variety, while in other cases the deposit may pass gradually from one kind to the other. It is therefore very difficult to secure a product from peat which shall have uniformity of structure, of cohesiveness or of fuel value, and impossible to do so unless artificial means are employed to insure this.

These physical characters have to be considered when the problem of preparation for market is being worked out, whether for individual bogs, or for general application, especially since all of the methods now in use, depend, more or less, upon compression and molding into some form of rather small blocks, which must take and hold their shape readily, and not disintegrate too easily when handled or burned.

It is manifest that the coarser types, or those of coarse and fine material mixed, will retain more moisture and air and be slower about drying, than the others and will thus be less satisfactory for making briquettes without some treatment before they are compressed. Such treatment of the coarser kinds is usually given in the form of grinding or kneading, or often a combination of the two, by the use of mills and toothed and smooth rollers. This treatment breaks up the coarse fragments, works out a large part of the included gases and air, and some of the water held by the various constituents, thus making the whole mass uniform in texture and reducing the bulk; for some processes of preparation, the finely divided kinds do not need such preliminary treatment so much as coarser ones, but in practice, it is usual to give all the same preparation in order that any coarse material mixed in with the fine may be broken up. In making machine-compressed blocks, the finer grained types of plastic peats need very little grinding or kneading, for they are homogeneous and compact already, but the coarser varieties need a good deal of preliminary treatment before they make a satisfactory product by such process.

In Southern Michigan, and less frequently north, there are quite extensive areas of the dark colored, often nearly black peat, which is sufficiently plastic so that it can be molded when wet, and which holds its form when dry. In the dry state it becomes almost as black and hard as coal; such material would not be greatly improved by being pressed through a mill, but would have to be crushed, if it were first dried and then pressed into briquettes.

The lighter colored and coarser types would need thorough grinding and much working over, before being put to any use, and it is often difficult to make them sufficiently plastic and cohesive to form good blocks even when they are molded wet. Certain components of this kind of peat, notably the grass and sedge leaves, may be sufficiently abundant and so poorly decomposed that they clog the rolls of the grinding mills and cause much trouble in handling. When ground, dried, and formed into briquettes by pressure, peats of this kind are full of irregular flat particles of sedge leaves, which arrange themselves with their long axes at right angles to the length of the block and thus develop cleavage planes in the briquettes, which cause them to exfoliate when burned, thus reducing the efficiency of the fuel, and to split away readily when handled, hence they do not bear transportation well.

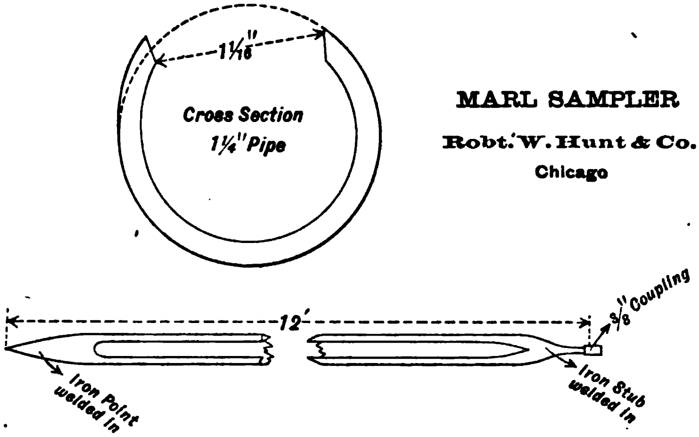
Prospecting Methods.

In the first examination of marshes, swamps, or bogs, for peat, attention should be given to the following matters and notes should be made regarding them: (1) The exact location by Township, Range and Sections; (2) The distance from the nearest transportation lines; (3) The approximate area of the surface of the peaty tract and character of the surrounding lands; (4) The kind of plant growth on the surface of the area, whether grasses, (or sedges), shrubs and mosses, or trees. If the latter, the kinds and size. If the trees have been cleared off or burned off, this should be noted, with the kinds taken off, if this can be determined. (5) The possibilities of drainage, streams through the bog or near by. It should be remembered that as peat is drained, the surface slopes in the direction of the main ditches, so that a certain amount of fall can be made by draining. (6) The depth of the surface layers to good peat, and of the whole deposit, should be tested in a few places, for even if of large extent, a very shallow bog is not worth much for fuel purposes. (7) The amount of decomposition of the lower layers below the surface litter, and its color and plasticity should be noted. It is usually true that the deeper parts of the bed are formed from different plants than are the top layers. These facts should be noted regarding every bog or marsh visited, whether any other work is done upon them or not. It is highly important also, in the more thorough preliminary investigation of a peat deposit, to find out, not only about the depth and extent of the beds and their purity, and the heating qualities of the peat, but to consider also the plasticity, the mechanical texture, the degree of decomposition, and the uniformity of the various beds at different depths below the surface. To do this thoroughly is no simple matter, and is often expensive, but the expense is slight compared with that caused by too hastily making the assumption that a peat deposit is available for use and establishing a plant upon it, and then finding that a marketable product cannot profitably be made from the peat.

Tools for Prospecting: In making the first prospecting examination of a deposit, the usual tool which is used is a long iron rod made of gas pipe, cut into convenient lengths, and provided with ordinary couplings, or unions, for screwing these together. The size of the pipes is a matter of some importance, since if too large it is very heavy to carry, and if too small it bends and breaks easily where the threads for the couplings are cut. Probably for practical work nothing smaller than ½ inch pipe should be used, except for light reconnaisance work, in which but few tests have to be made. For convenience in carrying, the lengths of pipe ought not to be greater than four feet, and in order that the couplings shall not work loose too easily, it is well to have each one pinned to one end of a length of pipe, so that the pipe and not the coupling will unscrew. The threads in the pipe should always be cut carefully and fit the couplings as perfectly as possible, and yet be neither too tight nor too loose. If cut slightly tapering they seem to work best, as they then hold firmly when screwed into place, but are easily released when it is necessary to take them apart. A pair of pipe wrenches, preferably the "alligator" pattern, should be taken into the field at all times, in case the sections of pipe get screwed together too tightly to be taken apart by the hands alone. In most cases, unless the beds are to be worked to an unusual depth, a pipe sounder of five four-foot sections will be sufficiently long for all practical purposes, since in actual practice abroad, the peat is rarely taken from a wet bog, such as most of the Michigan bogs are, from a depth of more than 10 feet.

Final Sampling: For taking samples from various depths, many devices have been used, one of the most common being a two-inch auger, which, if of the open spiral type, like an earth auger, is quite satisfactory if bored down into solid peat, and a clean hole made. If simply pushed down, turned around a few times to clean the pod, and then draw up, it is likely not to bring up a satisfactory sample; in fact, little dependence can be placed upon getting a clean sample by such a method, from even a few feet below the surface, and the auger is not recommended unless used carefully, in compact, solid deposits; of course in the nearly liquid types of deposit no samples can be taken by an auger.

Another form of sampling apparatus which has been used with good results is made by splitting a length of one or one and one-half inch pipe, and spreading it so that a narrow, longitudinal opening is made nearly the entire length. One edge of this is sharpened by filing it and raised above the other so that the cross section is something like the accompanying figure (Fig. 18). This is pushed down to the desired depth and then turned several times until the sharp edge has cut off enough of the surrounding peat to show its character. A removable pointed plug should be put in the lower end of this sampler to keep it from filling with peat as it is pushed down into the beds, unless a hole has been previously bored down about to the depth from which the sample is to be taken. If steel tubing is used for this form of sampler, it will be lighter and more easily sharpened and kept sharp than is the common wrought iron tubing which is ordinarily used.


MARL SAMPLER

Robt. W. Hunt & Co.

Chicago

FIG. 18. Hunt Marl or Peat sampler.

A sampler for taking small, pure samples from any depth, was used by the writer, and consisted of a short cylinder into which fitted a metal plunger, which, when pulled out a definite distance, locked automatically; in use, the cylinder was screwed on to the end of a gas pipe sounding rod and pushed into the peat the required distance, less the length of the cylinder. The rod was then drawn up until the catch-lock was heard to click and then pushed down the length of the cylinder, or a little more, in order to insure completely filling it. The sample thus obtained was free from all outside impurities.

Importance of Thoroughly Proving a Deposit: In making the tests for the final proving up of a bog, before preparing to exploit it, holes should be dug at regular intervals, to such a depth as will insure cutting through to the deeper layers of the deposit, from which large samples of material should be taken and worked up by the process it is proposed to use in developing the bog. The holes should be dug in parallel lines equally distant from each other and if marked differences are found in certain consecutive holes, which are considered of sufficient importance to warrant it, intermediate test holes should be made. For making such tests, some prospectors use a common, long-handled spade, others a post-hole digger or auger, and still others use a peat spade or slane, but the important thing is to have the testing at this stage done thoroughly and to such depth that there is no doubt as to the good quality and large quantity of the deeper layers of peat, which are frequently the only ones which are of value in the preparation of fuel for commercial use.

Factors Affecting the Commercial Value of Peat Deposits.

In considering the possibility of developing a deposit of peat, by constructing a plant, certain other matters than those mentioned above, have to be taken into account, as it is often upon such preliminaries that the financial success of the contemplated investment will depend.

Market and Transportation: Of primary importance is a good and steady market for the product, after it is ready to sell. With a standard article, well known and with large use, the location of the place of manufacture is not of great importance, since buyers will seek it to supply their needs. With a little known and practically unused commodity, however, competing with others of equal value which have been in use a long time and in which there is not only a closely organized trade and an iron-clad agreement between producers, who may also be favored in the matter of transportation, but also a close organization of retailers to control the prices and markets, the matter of an immediate and near-by market is not to be overlooked. The nearness or remoteness of market, is the more important, also, because of the bulkiness of all forms of peat fuel, and the ease with which it disintegrates when subjected to moisture, or to rough handling, so that it can be sold at less cost and in better condition near the place of production than it can if shipped long distances; moreover the loss from handling is much less after short shipments than after long ones. It would, therefore, seem probable that it would be unwise to attempt, in the beginning, before the peat fuel is well established, to exploit bogs which are far from some large town, and which are not on or near some well developed railroad line, which will give assurance of good freight rates and a sufficient number of box cars for the shipment of the finished product.

Area and Depth: The area and depth of the deposit is also a matter of importance, the area probably of more importance than the depth, since, according to European practice, the deposits are rarely worked below 10 or 12 feet in depth, although there seems to be no reason why, with dredges or even pumps, the peat from the deep deposits should not be used, if it has the proper texture and composition. The statement has been made that about 200 tons of finished peat fuel can be made from an acre of peat of average density, for every foot in depth, or, as is frequently stated, 200 tons to the acre foot. With this in mind, it is easy to calculate the amount of fuel which can be made from a bog of any size and depth, and whether it will pay to develop it. In this connection it is well to remember that the upper foot or more of the peat is often of no value for manufacturing into salable fuel, but most of it may be used in running the plant, with no other preparation than cutting it from the bog and drying it by exposure to wind and sun.

Physical Condition of the Peat: The importance of the physical condition of the peat in given bogs has been mentioned. This will depend largely upon the way in which it has been developed. If in a basin which had filled largely from top and sides, the peat will consist of a well defined top stratum from one to several feet thick of more or less fibrous and coarse, light-colored material, which has below it a deeper mass of darker, homogeneous, plastic peat, often very soft and full of water, but of generally good fuel value and easily handled by properly adapted machinery.

On the other hand, if the basin has been filled by stages of growth, from the bottom, the peat is likely to be coarse and fine alternately, or made up of mostly coarse, partly disintegrated material, and may have beds containing stumps and logs at intervals from bottom to top, which will make it difficult to work by the usual types of machines for cutting peat. In making estimates of the amount of peat contained in deep bogs, care must be taken not to overestimate this, for it has been shown by the experience of prospectors, and of railroads[1] crossing such deposits, that they are not infrequently not solid, but have only a relatively thin covering of dense peat, from 4 to 6 feet thick, formed of closely interwoven stems and roots of various plants, including trees, on the surface, below which is a body of water of considerable size which contains no peat or only suspended fragments of vegetable matter. Below this water may be more peat, but so far below the surface as to be useless. Such a condition is not revealed by testing with an auger, as the pod of the auger is filled with peat from the surface coverings as it is drawn up, unless very careful borings are made.

Deep Bogs with Thin Stratum of Peat with Water or Marl Below: Another matter of similar nature is the frequent presence of marl, several feet below the surface of seemingly deep peat beds. In one case, in which prospecting was done by the writer, in a bog which had been looked over for marl, and none found, and which was supposed, from auger tests, to be made up of solid peat, the peat was only 8 or 9 feet deep with good marl below. In another place the peat was said to be 10 or 12 feet deep by the owner who had often sounded it, and was found to be about 4 feet deep and the rest marl. The cause of the discrepancies was the replacement, in the auger, of the marl by peat as the tool was drawn through the latter, which apparently is a frequent occurrence in the use of the auger.

Sampling for Other Purposes Than Fuel: If the bog is being examined for peat for other purposes than for fuel making, such as paper or pulp stock, or for litter manufacture, similar precautions should be taken to see that there is an abundance of the proper kind of peat for the uses which are to be made of it. The best type of bog for these uses would be the one built up from the bottom with numerous layers of sedge and grass remains.

Chemical Composition and Ash: These should be determined by the chemist, together with the fuel value, before final arrangements are made for putting in a plant. The best way to test the fuel value, however, is to make actual working tests, under a boiler, in which samples of the fuel are used, made up in the machines to be used in the proposed plant, from the peat taken from the test holes made in the final prospecting. Such tests are expensive, but can be made very satisfactory, as they show the real efficiency of the fuel better than the ordinary chemical analyses and calorimeter tests. If the fuel does good work in these practical tests there will be little question about the amount of ash present.

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[1] See Part I, p. 154.

Possibilities of Drainage: These are usually considered of importance, and sometimes excellent bogs have been left unutilized, because they were not capable of being effectively drained. In Sweden, however, peat fuel has been satisfactorily and very cheaply made upon floating establishments of small capacity, and there seems no reason why the peat should not be excavated from the wet bogs, without draining them, by the use of scows and dredges just as ditches are cut through marshes. In recent practice in Germany, indeed, the peat is sent to the mill from the bog by floating it in a liquid form through shallow trenches, which have an artificial fall, into a storage basin, hence the more nearly the peat approaches the fluid condition when taken from the bog, and can still be handled, the better it is for the purpose, so that drainage is not an essential, or even a desirable thing, especially if some such system of transportation is used.

Character of the Surface Growth: A bog which has been cleared, is more desirable than one covered with a dense growth of small trees and bushes, and one free from stumps has that much advantage over that from which a heavy growth of timber has been cleared, but the matter of clearing up the surface is a relatively small one, since it can be done a little at a time, and need not be hurried, after a sufficient area has been cleared for actual work. From what has been said in the discussion of the development of peat deposits, it is evident that the surface vegetation, except in very shallow deposits of no commercial value, indicates nothing as to the origin of the peat, or its physical condition, or its fuel value, for the plants present may only recently have established themselves, and the only thing which they indicate is the position of the water level with regard to the surface of the peat.

Acidity: Some types of peat, notably the brown ones, are said to become nearly impervious to water after they are once thoroughly dried out, because the organic acids which they contain are colloidal, or gluelike, in form, and when they dry, they become insoluble, so that the acid, brown peats may make a slightly stronger and more resistant pressed block fuel than the black ones, but it is doubtful if in practice the difference would be of importance and it can be of no importance where briquetting after drying is resorted to, since the cementing effect of the acid is slight.

Sources of Contamination Producing High Ash Content.

Importance of Ash: The ash content has to be considered, because, if it is high, the fuel value of the final product from the bog must be reduced, and by so much the cost of handling increased, since the ash constituents are mineral impurities which do not burn, and in considering the availability of a peat deposit, for fuel manufacture, the possible sources from which mineral matter may get into the bog to increase the normal ash content, should be taken into account, of which the following are worthy of notice:

Flooding by Streams: A chief source of such matter is flooding by streams, which bring silts, muds and even sands into the basins through which they flow and deposit them, or leave them upon the part of their flood plains which they overflow. Streams flowing through a cleared and cultivated country are much more likely to have floods and carry abundant sediment, than those which flow through forest covered regions. Peat deposits along such streams, especially in the river swamps, oxbow lakes and bayous, and in their deltas in lakes, are usually so filled with the various forms of sediment that they have little if any fuel value.

Flooding by Rain Wash: Flooding by rain wash from higher ground, is a form of contamination to which many otherwise good deposits of peat have been subjected to in Michigan since the hillsides have been cleared and cultivated, and it is no uncommon thing to see sand and gravel piled several feet deep upon the surface of the margin of a peat bog, while the water of the adjoining marsh is colored a deep brown by the finer matter which has been carried in suspension and has not yet settled. Where such wash has been going on for any length of time, the ash content of the superficial layers of the bog is very high, hence if it is found that a bog is subject to flooding from high ground during heavy rains, the peat should be studied to ascertain how deep the silt has affected it, and if there is any means of checking the wash, since this may reduce the value of the bog after exploitation begins.

Spring and Terrace Bogs: Certain classes of peat deposits, notably those on terraces of streams, and on slopes, are formed by the outflow of springs. These are particularly likely to be high in mineral matter, for the water which is constantly flowing through and over them, has considerable dissolved mineral matter in it, which may be precipitated in contact with the air, especially after the excess of the gas, carbon dioxide, which most spring waters contain, has passed off into the air. Such mineral matters are calcium carbonate, calcium sulphate, or gypsum (in some regions), iron compounds and sometimes other mineral matters. The calcium carbonate is the most common of these substances and is generally precipitated by a plant, Chara, which grows in the shallow water of the spring outlets and often forms a considerable part of the deposit in which its remains can be felt as granular, gritty, particles scattered through it. Sometimes one of the mosses also forms deposits which are more stony in their character and of large size, one in Seville Tp., Gratiot county, covering an area of several acres. The iron precipitates first appear as a thin, oily-looking scum on the surface of the water standing in small holes and along the spring outlets, and later as a reddish, rusty-appearing sediment of hydrous iron oxide, "bog iron," farther along the stream, as thin, rusty streaks in the peat, or sometimes below it, in masses.

Not infrequently, when bogs of this sort are burned, the iron which was in the peat appears as a dark brown or even deep red deposit of ochre. The mineral matter of such bogs is also added to by the shells of mollusks, chiefly land snails, which are usually very abundant in them, and may be seen lying on the surface or buried in the peat. When to these internal sources of mineral matter is added the liability of flooding from the higher lands around, to which this type of bog is especially liable, it is evident that it is not usually worth while to consider spring-formed deposits of peat, of the terrace and mound types, as sources of fuel supply, in the region under discussion, even where they have good-sized areas, which is not, however, frequently the case.

Shore Wash in Lakes: In some larger lakes, and occasionally in small ones, there may be extensive bogs along parts of the shore, while other parts have sand, gravel or even marl exposures. During times of storm and high water, the waves and shore currents may carry a good deal of finer, silty matter to the bogs and in this way make the peat impure. Where it is found that after storms or strong winds, the marshes, under which the peat lies, are covered with muddy water, the top layers will be found to have an abnormally large amount of ash. Such bogs are frequently not so situated that they can be used profitably, even when they are extensive enough to be considered as worthy of exploitation; if, in any case, they are examined for this purpose, the question of the amount of ash in the lower layers of the peat should be given more than ordinary attention.

Mineral Matter From the Water of Lakes and Streams: This is of two kinds, that held in solution and that carried by the water, in the form of fine sand, silt or clay in suspension during floods or in less amount at other times, or washed directly from the high lands to the bogs. There is a considerable quantity of the suspended matter, which is so very fine that it remains suspended for a long time and eventually may become entangled by water plants, and upon their decay, become a part of the peat, or it may settle slowly to the bottom with fine vegetable matter and be incorporated into it. In order to become convinced of the importance of this factor, one has only to examine the washings from some of the floating aquatics with finely divided leaves, from even a small pond, under the low power of a compound miscroscope, for they will be found to consist quite largely of small angular particles of mineral matter, often silica.

Dissolved Mineral Matter: The mineral matter held in solution in the water, is a more constant, and, on the whole, a more important source of impurity to the vegetable matter which makes peat; in fact, it is the source of all mineral, or ash constituents, except those mentioned above, for the plants get all of their mineral matter from the soil waters, and build it into their tissues. Aside from that which is used in this way by all plants, there is a considerable amount which is precipitated in one way or another by the water plants, which goes to increase the amount of ash in accumulations of their remains.

Precipitation by Plants: Two distinct types of plants, the seed-bearing and the Algæ, precipitate calcium carbonate in considerable amount upon the outside of their leaves and stems, or, in the case of the lower Algæ, over the entire plant. Where the higher plants are most numerous, the amount of the mineral matter accumulated is small in comparison with the amount of vegetable matter formed, but where the Algæ, Chara and lower types, are the dominant vegetable forms, the amount of mineral matter is often so large that marl, and not peat, is formed. Where there is any considerable quantity of Calcium-secreting Algæ growing in the deeper parts of the lake or body of water (even shallow spring outlets an inch or less deep are not free from these plants, as pointed out above), the ash content of the resulting peat is certain to be high. It may be worthy of note here, that Chara, the important lime-secreting plant, not infrequently grows in shallow water among the bulrushes and sedges and contributes considerable mineral matter to the resulting vegetable débris and its presence in such places may often account for the presence of more mineral matter than could otherwise be easily explained.

Another type of Algæ, the Diatoms, secrete silica in the form of delicate transparent shells, and while these plants are very minute, their number is sometimes so enormous that their shells have made deposits of considerable economic importance in various parts of the earth. These plants are always present in the water of peat bogs, and their silicious shells undoubtedly add an appreciable amount to the ash of most types of peat.

An additional source of precipitation of dissolved mineral matter from the water of bogs, lakes, springs, and streams are certain filamentous Algæ which form local deposits of lime and iron in bogs and swamps, and at times this becomes sufficiently general to seriously affect the quality of the peat.

The chief contributors to the ash of the coarser types of peat, are sedges and grasses, which, in the course of their growth, secrete considerable quantities of silica in the cell walls of stems and leaves. This silica is then a normal constituent of peat, and is to be expected where the plants mentioned have had any considerable part, as is generally the case, in building up the deposit.

Another group of plants, representatives of which are sometimes found either growing on the surface of bogs, or in the water along their margins, in large quantities, has silicious cell walls. This is the Horsetail family, the Equisetaceæ, the surviving remnant of the Giant Calamites of the Carboniferous Age, which grew in similar situations, and by their growth and decay helped to form coal.

Relation of Deposits of Peat to the Bottom.

In relatively shallow peat beds, it is sometimes a matter of some importance to determine the quality of the underlying stratum of mineral matter, as this may, in some cases, affect the lower strata of the bog, rendering them impure, or make it difficult to harvest them.

In the Southern Peninsula of Michigan, ordinary till or boulder clay is a common type of material found below bogs. This never is found above the bottom of the peat, hence never interferes with working the bog to the bottom.

Where clay forms the substratum, however, as it often does, the lower layers of peat are usually impregnated with it, and it is apparent that at the time the peat was laid down, conditions were such that considerable mud was being held in suspension from time to time in the water of the depression in which the bog grew up and was deposited with the peat. The clay content of the peat may continue to be excessive for a foot or more above the bottom, so this amount of material has to be left in the bog in utilizing it for fuel manufacture.

In the Northern Peninsula, many of the shallower bogs have been built up over sand, and in such cases there seemed to be no intergrading between the sand and peat. Indeed, it is not easy to see how sand could be mixed with the peat by ordinary water action, since the force of current which would carry the sand would wash the vegetable matter all away. In some cases there were thin layers of clay between sand and peat, but the amount of this material was small and its effect upon the peat did not seem to extend above the bottom to a greater distance than an inch or two.

When, as has been mentioned above, marl lies below the peat deposit, from the origin of the two substances, there is likely to be a zone of some thickness in which they will be mixed so intimately that the peat will be of no use for fuel. Such a zone will show the presence of the marl by its grayish color when dry, and the large per cent of ash which even the darker peat leaves when burned. This zone of mixed material may vary in depth from a few inches to two feet or more, but usually it is quite narrow, although where present it must always be taken into account.

Bog iron is sometimes found at the bottom, a short distance below peat beds, but rarely in them, except as indicated above. It usually forms a hard pan, or, frequently, irregular masses, when it is at the bottom of a bog, and may, in some cases, render it difficult to use machines for cutting out the lower layers of the bog.

Summary.

Color: The type of peat which would be called a good commercial peat for fuel use, that is, one which could be readily handled by some one of the processes now in use, and make a desirable type of product, at a price which would not prohibit its manufacture, should have a color, when wet, which varies from medium to dark, rich brown, or to nearly, or quite black; the deeper layers of peat are frequently darker than those at or near the surface; in a few, probably rare, types however, the color may be much lighter. When dry, good peat may vary in color from medium light to dark brown of the richer shades or to black. That which shows much straw color when dry, should be looked upon with more or less suspicion, as should those kinds which are of light brown shades when wet, although the degree of decomposition and structure should be considered in connection with color.

Those samples which show much chalky matter when dry, or have a rusty color running through them in streaks, or are generally rusty when dry, are probably impregnated with lime and iron and will run high in ash. If the dry peat shows grayish, either in streaks or generally, it is likely to be rich in sediments and unusable for fuel.

Weight: Good average peat, when air dry, contains from 15 to 25 per cent of water, and weighs, without compression, about 12 pounds or more per cubic foot as cut from the bog. Those types which are darker and more compact than the average are heavier, while the ones which are of light color usually weigh less. A very heavy sample which has not been compressed, should be rejected as certain to contain too much ash, while a very light one is liable to yield a finished product that will be so bulky as to be at a disadvantage in the markets, because of high freight rates, and the amount of storage room which it requires, as compared with other fuels, for it must be borne in mind that peat fuel, unless in the form of coke, must be stored under cover, and since its bulk is eight times that of coal of the same heating capacity, it can readily be seen that the very light weight kinds, will be at a disadvantage, as they may require 15 to 18 times as much space as coal which will give the same amount of heat.

Texture: The importance of considering the texture and coarseness of peat must already be apparent from what has been written, regarding the matter. In general, the coarser peats are lighter in color and in weight than those of finer texture, which is in part due to the greater age, and more complete decomposition of the latter, and in part, to the different species of plants from which they were derived and different conditions under which they have been formed. With fineness of texture goes greater plasticity, which is desirable to a degree, in peat to be used for fuel manufacture.

While peat of the coarser types will usually give a fuel that burns readily, with a good degree of heat and with a minimum of ash, it yields a more bulky fuel, it is likely to break up quickly on burning, it needs much more preparation before manufacture, is more difficult to dry and keep dry, is harder to compress, and is almost certain to produce easily broken briquettes. On the other hand, the plastic, black peats are higher in ash, are more difficult to burn, and are harder when dry, reaching nearly the consistency of soft coal, which makes the compressed blocks durable but not unreasonably hard to crush, if briquetting, after drying, is resorted to.

Relation of Ash to Commercial Value.

In considering this matter, it is assumed that no peat having over 20 or at most 25 per cent of ash would yield heat enough, so that it would find a continued market, but when the ash of the dark colored peats, which are highest in ash, is below 15 per cent, it would usually find buyers, if it burned well, as the ordinary consumer will not be over particular regarding the per cent of ash in the fuel he buys, as is shown by readiness with which all kinds of coal and wood are purchased. The apparent amount of ash from peat fuel is very small, because of the large bulk of the fuel and the small bulk and freedom from cinders and clinkers of the ash, which makes it seem that the absolute per cent is small also. If, as is frequently done in Northern Europe, a body of peat is utilized for generating steam to run a single factory, using it in lieu of other fuel brought from a distance, the various precautions regarding ash and quality, texture and other characteristics may be waived, since, in such a case, proximity to the factory and quantity of material, are of more importance than quality. There is no difficulty in generating steam quickly and in any quantity, by using air-dried cut peat, even of rather poor quality, and with a small cutting and compressing plant, the efficiency of the fuel may be readily increased, so that at a small cost per ton, an excellent product, and a good substitute for coal or wood can be obtained from the immediate vicinity of the factory. That such individual plants, making a few tons of peat fuel per day, from the numerous small bogs scattered through Michigan, are not in existence, is evidence either that the owners of small factories are sufficiently prosperous, so that they do not need to practice small economies, or that they are not yet fully aware of all of the resources which may be exploited to their advantage.

Parmelee[1] divides the peat tested by him into three classes, (1) high grade peat, ash ranging between 0 and 10 per cent, (2) medium grade peat, ash 10 to 15 per cent and (3) low grade peat, ash 15 to 25 per cent. The lowest ash reported in this series is 5.04 per cent of the weight of the peat after it had been dried in an oven at 105° C. until the weight was constant and the number of heat units obtained from this sample was 5,876 calories. The heating value diminished as the ash content increased, in these tests, as would be expected, but not regularly, a sample with 8.34 per cent ash developed 5,521 calories, while another with 6.24 per cent ash developed only 5,098 calories, a less amount than another with 14.26 per cent ash which was reported as having a heating value of 5,193 calories. Still another sample with 16.44 per cent ash had a heating value of 5,117 calories. In general the low grade peats ran below 4,500 calories, the medium grade peats below 5,000 calories, and the high grade peats between 5,000 and 5,900 calories, only a small number, however, going above 5,500 calories. These tests were all made with peat dried in an oven at 105° C. until the weight was constant, hence give higher heating values, than would be obtained with air-dry samples, as the author notes, and also for the same reason, higher ash percentages. The same lack of definite relationship between heating value and ash content is shown in the discussion of Allen's analyses of Michigan peat below.

Location and Extent of Peat Beds in Michigan.

As has been stated in the part of this work dealing with the Northern Peninsula, the greatest continuous area of peat in the state lies along an extensive tract of flat country in the eastern end of that peninsula. In the Southern Peninsula,[2] there are no areas comparable with this in extent, and relatively few covering more than a few hundred acres. Of these, the most extensive lie in river valleys and are hence likely to be shallow, and more or less affected by silt which has been brought into the valleys from the hills or by overflow from springs and streams. Of the smaller areas of bog and swamp, there are many in the morainal, or hilly, region north of Detroit, in Oakland county, and extending across the state east and west as well as northward. If one takes a map of the state and examines it for regions where lakes are most numerous, then visits these, he will, in such regions, find bogs and swamps filled with more or less extensive beds of peat, since the lakes indicate an abundance of undrained or partly drained depressions, and, in these, bogs have grown up, as shown by the parts of this report describing the development of peaty formations. The original distribution of swamps, containing more or less peat, in Michigan, is shown by the maps, (Plates XVI and XVII).

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[1] Parmelee, C. W. & McCourt, W. E. A report on the peat deposits of Northern New Jersey. Ann. Report of the State Geologist of N. J. for 1905, p. 261, Trenton, N. J., 1906.

[2] See also Winchell, A., Peat in Michigan, Leavitt's Peat Journal I, 1, Boston, 1867.

These deposits range in depth from a few feet, to as much as 60 to 70, though more often only to 25 or 30 feet, and from a few acres to a series of connected basins, which may cover many hundreds of acres, and in which the depth of the peat may more than compensate for the relatively small area. In some of these basins, however, the peat is shallow, being underlaid by marl a short distance below the surface. On some of the broad, flat divides and especially in the valleys lying in the morainal region of the state, there are excellent deposits of peat of good depth and quality, some of which have been brought under cultivation, however, and are not available for exploitation for fuel, or other purposes.

There is no question in the minds of those who have investigated the matter, or of that of the writer, that there is an abundance of excellent peat for all the uses to which the material has been put, to be found in Michigan and that good deposits for the manufacture of fuel, on any reasonable scale, are to be had near enough to the large towns, so that a good market can be built up as soon as the product is made upon such a basis, that it can be profitably sold in competition with moderate priced, or cheap, wood and coal.

For those types of peat which can not be made into transportable fuel, special forms of utilization could be devised, such as those suggested by Adolf Dal in an article in the London Engineering Magazine, November, 1902. He recommends that the peat of large deposits be turned into electric energy at the beds, and conveyed to the manufacturing centers in that form, rather than try to transport it in fuel form. There is also the possibility of distilling it, and piping the resulting gases long distances, for use in gas engines and for heating and lighting purposes. It seems probable that such methods of exploitation would be quite as satisfactory, and more simple than any method for converting the peat into a portable fuel, except possibly into peat coke, which would be done in any case, if the gas were the object of the utilization.

The Composition of Michigan Peat as Shown by Analyses.

The following analyses, a few of the many which have been made by various chemists, and others, who have investigated the suitability of our peat deposits for fuel,[1] show that these compare favorably with similar deposits in other parts of the country and of Europe.

Analyses by J. R. Allen.

The following report of analyses of peat from three counties in Southern, and one in Northern Michigan, was kindly furnished the Geological Survey for this report by Prof. John R. Allen, of the Engineering Department of the University of Michigan.

Prof. Allen makes the following explanatory statements of the methods used by him in testing the peat samples.

"The analyses, the results of which follow, were made solely for commercial purposes, without any thought of publication. They are, therefore, not as complete as they would have been had the original intention been to publish them.

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[1] See also Geol. Surv. of Mich., Vol. VIII, Pt. 2, Coal of Mich., p. 119.

Before being tested, the peats were thoroughly dried at a temperature of about 160° F. The reason for drying at such a low temperature was that it had been found that peat loses a part of its volatile matter when dried at a temperature exceeding 200° F. Tests were made with a Parr calorimeter. The instrument used was a special one of large size, to accommodate the large bulk of peat that it was necessary to use in order to have sufficient weight to give accurate results, but otherwise it was the standard Parr[1] calorimeter.

The chemical analysis of the peat was made in the ordinary manner with a platinum crucible. The crucible was filled with the peat, covered with a platinum cover, weighed and heated until the volatile matter was driven off. Then the crucible and residue were weighed and this weight subtracted from the original weight of the crucible and peat, which gave the weight of the volatile matter. The cover was then removed and the remaining material heated for about 24 hours over a gas flame until all the fixed carbon was driven off. The crucible and contents were then weighed and the result subtracted from the previous weight, the difference being the fixed carbon. The crucible was then cleaned of the residue and weighed, and this weight subtracted from the previous results; this gave the weight of ash. As the tests were made only for commercial purposes, no peats containing over 20% of ash were fully tested. Peats with over 20% of ash were considered unsuitable for commercial purposes.

The results of the tests are given in the following table:".

Number.	County.	Per cent ash.	Per cent fixed carbon.	Per cent volatile matter.	B. T. U.'s per lb.	Remarks.
1	Luce	4.4	....	....	10,600	Peat very fibrous in appearance.
2	Luce	....	....	....	10,000	
3	Luce	4.0	....	....	8,250	Very fine structure.
4	St. Clair	3.5	....	....	9,550	
5	Jackson	9.0	27.3	63.7	8,000	
6	Jackson	3.2	28.6	68.2	8,600	
7	Jackson	8.8	24.0	67.0	8,200	Dense black color.
8	Jackson	5.15	30.0	64.7	9,700	Very light peat.
9	Jackson	5.8	25.0	69.8	10,280	Very light peat.
10	Jackson	7.6	31.0	61.3	8,400	
11	Jackson	10.3	29.4	60.5	8,750	
12	Jackson	10.1	30.8	58.8	9,100	
13	Washtenaw	7.7	30.9	61.5	8,900	Dark reddish color.
14	Washtenaw	10.1	23.6	66.2	8,200	
15	Washtenaw	10.2	26.7	63.2	8,600	
16	Washtenaw	1.8	30.3	68.0	9,500	Fibrous structure.
17	Washtenaw	1.3	29.8	68.5	10,300	Fibrous structure.
18	Washtenaw	2.0	28.0	70.0	10,100	Fibrous structure.
19	Washtenaw	18.8	26.3	55.2	7,550	Celery farm land.

The per cent of ash plus the per cent of fixed carbon will give the per cent of coke obtainable from any sample.

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[1] For description and figures of the Parr calorimeter, see Geol. Surv. of Mich., Vol. VIII, Pt. 2, Coal of Mich., pp. 73-76.

On making a comparative study of these analyses, it becomes evident that the ash content of the 18 samples in which it was determined, is low, since in only one of these does it rise above eleven per cent of the total weight of the dried peat. It is difficult to compare these results with those which Parmelee obtained from work on the New Jersey peats, and which have been cited in another place, since those were based upon tests of peat which had been heated to 105° C. or 221° F., before weighing, this temperature involving some loss of volatile matter, as pointed out above, and therefore higher ash in the final statement of analysis, but it is fair to assume that all except one would fall well within the two classes of high and medium grade which are made by that author.

Considered by themselves, Prof. Allen's figures show, as do others also, that heating value does not vary regularly according to any except very considerable variations in the ash content, and that there is no close and definite relation between the heating value and any of the elements reported here. Thus, if these analyses be arranged in order of their heating value, the highest first, and compared with another arrangement in which the lowest in ash is placed first, No. 1 in heating value is No. 7 in ash content. The relations are still farther shown in the following table, made up by arranging the analyses in order of each of the elements of analysis reported, all except the ash from high to low per cent, and the ash from low to high per cent:

Table of Comparative Values of Peat Samples Given Above to Show the Lack of Relationship Between Heating Value as Expressed in B. T. U. and Other Factors Reported.

Original number.	Order for heating value, B. T. U.	Order when arranged according to per cent of ash present.	Order when arranged according to per cent of fixed carbon present.	Order when arranged according to per cent of volatile matter present.	Remarks.
1	1	7	....	....	Only ash and B. T. U. reported.
17	2	1	6	3	
9	3	9	13	2	
18	4	3	9	1	
2	5	....	....	....	Only B. T. U. reported.
8	6	8	5	8	
4	7	5	....	....	Only ash and B. T. U. reported.
16	8	2	4	5	
12	9	14	3	14	
13	10	11	2	11	
11	11	17	7	13	
15	12	16	11	10	
6	13	4	8	4	
10	14	10	1	12	
3	15	6	....	....	Only ash and B. T. U. reported.
7	16	12	14	6	
14	17	15	15	7	
5	18	13	10	9	
19	19	19	12	15	

In a general way the table shows that the higher calorific values are obtained from the peats lowest in ash, and where the ash is present in large quantity, the heating value is reduced, but as stated above, within the range of ash for high grade, commercially valuable peats, this relation is not demonstrable, and a sample with only three per cent of ash may yield less heat units than one having 9 or 10 per cent. In like manner it can readily be seen that the other components usually determined in peat analyses have little demonstrable connection, within limits, with the heating value.

For explanation of these irregularities it seems probable that it will be necessary to consider the type of plants which predominated in the plant associations from whose remains the peat has been built up, the degree of decomposition, the general conditions under which the plant remains were converted into peat, and other minor factors, which, taken together, make the problem one difficult of solution, especially as many minor accidental causes may affect changes in the ash content, and complicate the problem in other ways. It is evident also, from what has been shown regarding the varying origin the different strata of the same bed of peat, the type of plant remains will vary, generally, from layer to layer, from the top down to a considerable distance and that it would be often impossible to determine quantitatively the different species of plants present in the peats, even when it would be easy to tell what ones were present. The peat which contained much of the remains of the resinous coniferous trees would have a high heating value, and should be low in ash if mineral matter from other sources than the plant débris were not present.

It is not likely then, that peat, lacking as it does homogeneity of structure, composition and origin, can ever be depended upon to give uniform heating tests, even when the samples are collected from the same bed, and with considerable care, but in spite of this fact it will usually be advantageous to thoroughly sample and test all beds which are to be commercially exploited before any development is attempted, since in this way only will it be possible to determine the quality of the peat.

The analyses given above indicate that Michigan peat may run very low in ash and that it has a calorific value quite equal to the best grades of peat found in other parts of this country and of Europe, as examination and comparison of the records of analyses will show.

Analyses by A. N. Clark.

Samples collected near Ludington by A. N. Clark, Alma.

Sample No.	Per cent H_2O.	Per cent sand.	Per cent dry peat.	Heating value.
1, 3, 5 and 7	86.5	1.6	11.9	B. T. U.
4	87.0	3.0	10.0	
2	90.0	2.0	8.0	
6	88.0	....	....	8,633

No. 6 was the only one tested to determine the heating value and was dried in an oven at 105° C. until the weight was constant, before testing. The heating value of this sample is about that of good hard wood with no treatment except thorough drying.

In the series of four samples from a large bog in Sanilac county, given below, there is a greater divergence in the ash and water content of the various samples. It is an interesting fact that Nos. 1 and 2 are from the same hole, No. 1 from about 5 feet below the surface, and No. 2 about 10 feet. No. 3 is also from about 2 feet below the surface, and No. 4 about 5 feet from another hole about 300 yards from the one from which Nos. 1 and 2 were taken.

Analyses by J. N. Courtney.

Sample No.	Per cent H_2O at 106°C.	Per cent ash.	Per cent combustible matter.
1	83.82	0.88	15.30
2	75.26	3.56	21.18
3	86.94	0.58	12.48
4	81.34	2.86	15.80

The same series of samples was also dried at 106° C. and the carbon, ash, and calorific value determined as follows:

Sample No.	Per cent carbon in peat dried at 106°C.	Per cent ash.	Heating value in calories.	Heating value in B. T. U.
1	47.35	5.70	3,826	6,866
2	32.10	21.10	2,594	4,655
3	35.60	4.45	2,876	5,162
4	30.00	13.00	2,424	4,350

These analyses are instructive, in that they add to the evidence showing that the heating value of peat high in ash may be greater than that with a much lower ash content, and they also indicate that in some bogs the peat from lower strata may have less water than that from nearer the surface; they also give ample testimony as to the high quality of Michigan peat as fuel.

A further idea of the average quality of Michigan peat is given by the analyses for the Chelsea company by W. H. Allen, cited on page 119 of the report on coal (Mich. Geol. Surv., Volume VIII, Part 2), the average of which is as follows:

Moisture and volatile combustible	59.192
Fixed carbon	31.006
Ash	9.802
	100.000

The annual report of the State Board of Geological Survey for 1902 (p. 15) also contains the average result of 10 analyses by Prof. Delos Fall, of the MacMillan Laboratory at Albion, as follows:

Moisture and volatile combustible	64.935
Fixed carbon	28.843
Ash	9.222
	103.000

Mr. Waterbury, in connection with the Haslett Park sink hole, already referred to, had the following three analyses made at the Agricultural College:[1]

Sample No. 1.

Taken south of hole and one foot from surface.

Moisture	8.92	per cent
Organic matter	79.06	" "
Mineral matter	12.007	" "
Total	99.987	" "

Sample No. 2.

Taken 100 feet south of hole in crust, from ground exposed by a tree which had been blown over.

Moisture	10.	per cent
Organic matter	80.	" "
Mineral matter	10.	" "
Total	100.	" "

Sample No. 3.

Taken from water at north side of hole.

Moisture	10.57	per cent
Organic matter	83.74	" "
Mineral matter	5.691	" "
Total	100.001	" "

The percentage of ash in the Allen, Fall and Waterbury analyses is fairly constant.

Fuel Value of Peat.

Raw peat as it exists in the bog is made up of from 85 to 90% or even 95% of water, 8 to 13% of combustible matter, and about 2% of mineral matter or ash. It is evident that such material will not burn, until some of the water is dried or drained from it. If weighed when cut from the bog the heavier and denser qualities may weigh as much as 100 or 125 pounds to the cubic foot, but if allowed to lie on the surface of the ground a few days the water will be reduced to about one-half its former quantity and a still farther exposure to sun and wind reduces it to from 15 to 25%, where it remains stationary, or gains and loses slightly, according to the amount of moisture present in the air which surrounds it. In this air-dried condition, it will have about one-half its former volume, and will weigh from 12 to 40, or even 60 pounds per cubic foot.

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[1] The Michigan Engineer, 1903, p. 39.

If set on fire, in the air-dried condition, the lighter and more spongy kinds of peat take fire at about 200° C. and burn briskly, with a red, smoky flame, and give off a characteristic, strong, pungent odor, due to the destructive vaporization of the imperfectly carbonized organic matter. The denser, more compact kinds do not take fire so readily, burn more slowly and in some cases require a higher temperature to start the combustion. The ash of peat is light and powdery and small in bulk, compared with that of the original blocks, and when the surface of the fire is covered with ash, or the draft is reduced to the minimum, the fire is able to maintain itself indefinitely in a smouldering condition, as long as the supply of fuel lasts, it is said because the peat contains a quantity of oxygen in composition, in excess of that possessed by other fuels, and some of which becomes available to support combustion, when the material is decomposed by heat. For the same reason, peat fuels do not require as much draft as other fuels.

Compared With Other Fuels: In crude peat the heating power is small as compared with coal, only about one-half as much, or more exactly the ratio is given as varying from 1:1.6 to 1:1.8, or from 5-8 to 5-9; and it requires for the same evaporating effect from .8 to 18 times as much bulk of crude air-dried peat as of coal, hence large storage room and good-sized fire-boxes are required for the fuel in this form and it is for this reason and also to increase its efficiency, and give it staying power, that various processes of compression, etc., have been devised, In spite of its disadvantages in the more bulky forms, either of the air-dried, hand-cut blocks, or of the compressed blocks, it is reported by those who have used it to be a very satisfactory fuel for all domestic uses, that it is easily kindled, burns freely, gives a rapidly developed and strong heat, is light and easy to handle, and very clean, and with it the fire is easily regulated, for any purpose. For heating-stoves it is also well liked, giving out a gentle but sufficient heat. In burning it, its value and the amount of satisfaction it gives, is said to lie as much in the way it is handled and the form of stove used, as in the fuel. In Europe, where it is extensively used, very few special forms of stoves have been devised for the use of peat fuel, but it probably should be burned in smaller quantities, in less draft and with narrower grate openings than are used with coal and the fire should be tended more often. For open fires in grates, it is said to be a good fuel, and, by some, to be superior to wood. The smoke from open peat fires is said to be beneficial in cases of throat and lung diseases.

When used for the generation of steam under the boilers the manufacturing establishments, power and lighting plants, however, the efficiency of this fuel, in comparison with others which are to be found in the market, is at once questioned, and if it is found that the same money invested in any other fuel will produce as much or more steam, or more heat units, than peat, or can insure a more easily obtained and certain supply, or even one liked better by the men who handle it, the probabilities are much in favor, in most cases, of the other fuels being given the preference and the use. The makers of peat fuel, then, have to produce a fuel that is cheaper, better and more convenient than those already in the market, and must insure a sufficient supply the year round, if they expect it to be generally used for the generation of power, as it must be to make large investments in peat fuel factories profitable. Considering now the heating power of peat fuel of various types, it is well to inspect carefully the following table[1] in which its theoretical value is compared with that of other, commonly used, and easily obtained fuels. The quantity of fuel taken in each case is one pound:

	B. T. U.
Wood	5,760
Ordinary air-dried peat	6,840
Pressed peat	7,290
Bituminous coal	11,000
Ordinary gas coke	12,060
Peat coke	12,676
Semi-bituminous coal	13,000
Peat briquettes	13,330
Charcoal	13,804
Anthracite	14,600

The B. T. U. (British Thermal Unit), is the amount of heat required to raise a pound of water from 50° to 51° F. (Tait). The French unit, or calory, is the amount of heat required to raise a kilogram of water from 0° C. to 1° C., and is occasionally used in quotations in this paper. The relation between the two units is such that Calories may be changed into British Thermal Units by multiplying the quantity to be converted by 9 and dividing by 5. From this table it seems that peat either air-dried or pressed into blocks, is theoretically a more efficient fuel than wood and not so good as good bituminous coal or coke.

It must be remembered, however, that both ash and moisture affect the heating value of peat, as shown by the table given below, cited by Parmelee,[2] from Hausding's Handbuch der Torfgewinnung.[3]

	Calories.
Dry peat without ash	6,500
Dry peat with 4% ash	6,300
Dry peat with 12% ash	5,800
Dry peat with 30% ash	4,500
The same peat with 25% water	4,700
The same peat with 30% water	4,100
The same peat with 50% water	2,700
The same peat with 0% water and 15% ash	5,500
The same peat with 25% water and 0% ash	4,700
The same peat with 30% water and 10% ash	3,700

As the reports regarding the calorific value of fuels, including peat, are made from tests upon samples as free from moisture as it is possible to get them, the value of the fuel in actual working tests is usually considerably less than that indicated by the laboratory determinations. This must always be true of all forms of peat fuel, except peat coke and in certain types of seared briquettes.

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[1] See also the table in Mich. Geol. Surv. VIII, Pt. 2, p. 118.

[2] Parmelee, C. W. A report on the peat deposits of Northern New Jersey. Ann. Report of the State Geologist of N. J., 1905, p. 237.

[3] Hausding. Handbuch der Torfgewinnung und Torfverwertung, 2nd Ed. Paul Parey, Berlin, 1904.

Pressing the peat increases its heating power somewhat, and coking it about doubles its value as a heating agent, but does not bring it up to the standard of the best anthracite, although it makes it approach it, since tests reported by various authors give the calorific value of the best grades of Scranton (Pa.) anthracite, as 13,805 B. T. U., and briquetting is even more efficient, since the heating value of peat briquettes ranges from 9,000 to 12,000 or even to 14,000 B. T. U., thus equalling anthracite as a heat producer.

Aside from the evidences of actual heating power, admirers and others who have used peat fuels for generating steam in boilers, state that it gives a quick and lasting heat, raising steam in about one-half the time taken for coal, that it is nearly smokeless, forms no ash of any consequence, makes no clinkers whatever, or cinders, is entirely consumed in the fire-box, none dropping into the ash-pit, makes no soot, does not corrode the grate bars, fire-boxes or boilers, because of its freedom from sulphur, does not clog up the flues with any form of deposit, and that it is the most easily handled of all fuel. Farther, in burning under a boiler, the volatile hydro-carbons of peat are not driven off in a black smoke, as with bituminous coals, but burn above the bed of fuel, thus making a quick, hot, fire, which raises steam rapidly, and the temperature is afterwards maintained by the slower combustion of the fixed carbons. The facts that it ignites so readily, burns up so completely and gives a high temperature without producing cinders, sparks, soot, clinkers, and but a very little smoke, tend to increase its actual efficiency; and while ordinary coal is capable of giving more heat, pound for pound, when usual forms are taken into consideration, it clogs the flues with ash and soot, covers the boiler with a constantly increasing film of rust, destroys grate bars, is not all burned, and in other ways decreases its capacity for generating steam, so that much of its theoretical superiority is lost, and even if these things were not so, when the comfort and convenience of the public are taken into account, and the defacement and damage to property by soft coal smoke, the smokeless feature of peat combustion is alone worth some sacrifice of heating power. As to cost of production, the peat, occurring as it does, at, or just below, the surface of the ground, is mined with less danger and much more cheaply than it is possible to mine coal, and if it needed no further preparation than digging, could be produced for a very small sum per ton. In the form of air-dried, slightly compressed blocks, an acceptable and quite efficient form of peat fuel, it can be produced at from 75 cents to $1.25, or $1.50, per ton, and with automatic machinery, on a large scale, probably for less even than the lower figures, where some of the more highly decomposed, plastic types of peat are used.

But it has been pointed out above that the heating value of this product is only about 1:1.6 to 1:1.8 that of coal, and that the bulk is rarely less than eight times as great as coal of the same heating power, and may be, for the lighter kinds of peat, much more. These are disadvantages, and in the several ways already discussed, but two tons of peat, prepared in this way, will produce more heat than a ton of coal, so that the chief problems involved in introducing it for general use, are the cost of transportation, and of storage under cover, since in this form it can not be long exposed to the weather. The first of these problems is solved where cheap transportation can be depended upon, or by using the peat near the bogs from which it is taken, and the second is readily dealt with in most cases, after consumers have learned the value of peat fuel.

As Affected by Methods of Preparation: Peat is, however, most easily handled, and gives results most nearly in accord with those obtained from the `use of an equal weight of the best coal, when pressed dry into the form of small, compact briquettes, either alone, or with some other fuel, such as coal-slack, sawdust or some binding material, and it is to put it into this form, or one even more compact, cheaply, quickly and satisfactorily, that the energies of experts in dealing with this difficult matter, have been bent for many years. The chief problem involved, seems to be to find some way in which peat taken from the bog may be quickly and efficiently deprived of the water which is in it, and compressed rapidly, cheaply and continuously into briquettes, so that a constant production of the finished product can be insured, on a scale sufficiently large to warrant the maintenance of a plant involving, perhaps, the expenditure of a hundred thousand dollars or more, for establishment and equipment, for while smaller units may be built, the cost of running these is apparently disproportionately great, and the returns reduced by that amount. The great obstacle to success in these efforts is found in the fact that the real problem, as stated in simplest terms, is how to recover from a mixture of 85 to 90 per cent of water and 10 to 15 per cent of peat, this small portion of the latter substance, which, when received in a dry state, and burned, will only give heat enough to dry the water from one-third as much more. It is evident that such a problem is not easily solved if the fuel has to be all dried out by artificial means. It is undoubtedly a vital objection which can be urged against all systems of artificially drying peat, that they use three times as many heat units as the resulting fuel will produce, and therein lies the chief reason why such processes have not, in the long run, proved profitable, even where a large amount of waste fuel, in the form of peat refuse, has been available. The cost of drying, figured in tons of peat, is three tons of dry peat, or its heating equivalent, for every ton of dry peat produced, and after it is dried, to this must be added, to determine the selling price, the cost of digging, taking to the drying machinery, the removal from this to the presses, the operating and maintenance of these, the interest on capital and the charges for storing and selling.

Questions naturally arise at this point, as to why the water is not pressed out, thrown out by the use of centrifugal machines, or even filtered out. As to these questions, it may be said that very many attempts have been made to press the water from peat, the most exhaustive and complete of which, were conducted with great care and at large expense under the auspices of the German government. These were on a factory scale and resulted in practically total failure. Peat containing about 80% of water was given a pressure of more than two tons per square inch and when taken from the press still contained over 63% of water. In a report to the government of Norway upon some of the German experiments, which he had followed with care, J. G. Thaulow pronounced them to be complete failures, as it was shown by them that it was difficult to reduce the water to even 66% by pressure alone, and to get even this result required such a great outlay of capital, and such high remaining costs that the expense was all out of proportion to the output. Similar results reported from Canada on the use of hydraulic presses, and from other experiments, are not to be doubted and it is evident that pressure will not expel the water from peat.

Almost the same results have been obtained from attempts to drive the water from peat by the use of centrifuges, and it becomes evident that some internal cause for this behavior must be sought. This was pointed out in the first part of this report (p. 161), namely, that the water in the peat is largely held in the walls and cavities of the cells and vessels of the partly broken-down plant tissues, from which it can neither be squeezed by pressure, nor thrown by whirling, and no amount of contriving machinery is likely to make it possible to do this.

A recent process devised in England, it is claimed, breaks down, to a certain extent, the plant tissues in peat by electrical action, the mass under treatment being at the same time heated by the passage of the current, so that the water liberated is evaporated, but, when it is known that one unit of electricity, cannot develop more than 3,410 heat units, and that about 3 pounds of coal are required to generate this, it is difficult to see how such a method can successfully compete with evaporation by direct heating. If the coal, or other fuel used for the generation of electricity in the above process, were burned directly to heat the peat mass, it would produce more than 10 times as many heat units than are obtained by converting its energy into steam, then to electricity and back again to heat by the resistance offered to the current by the wet peat.

Still another, and apparently a perfectly feasible device for getting rid of the excess of water in peat has recently been described by a writer in Engineering.[1] By the method there discussed the excess of water from peat containing about 95 per cent of water, in which condition it reaches the factory through ditches from the dredging machines, is allowed to drain down to about 80 per cent and then is fed directly into the boiler where the water is evaporated and the steam pressure raised until sufficiently high to run engines and pumps and furnish heat to dryers, etc. The peat obtained in the dry state as the result of the evaporation is briquetted and used under the boilers. If peat with a less amount of water than the 80 per cent is used in the boilers, an excess of the amount of dry fuel required to run them is obtained, and may be briquetted and sold, but with this less fluid peat, the amount of energy used to work the feed-pump and briquetting machine for the boiler is greater, and with very dry peat may be about 30 per cent of the whole energy produced by the boiler. It is evident, therefore that only a relatively small amount of peat briquettes in excess of the needs of the boiler could be obtained by the use of the peat boiler, but large plants for the manufacture of peat fuel, or any form of peat product, could use this type of boiler for the production of fuel as well as steam, for driving the engines and other equipment requiring steam, instead of using the old type of boiler, and drying the fuel by some more expensive or time-consuming process.

After all this experimentation, it has been concluded by the most careful engineers working on the subject, that the most feasible way to dry the water from peat is by evaporation, using artificial heat, but as has been pointed out, this is too expensive to be practicable for the results obtained, and the processes or treatments which are proving most successful, are those which provide large covered spaces upon which great quantities of peat, after it has been ground and kneaded and slightly compressed into blocks, can be exposed to drying winds out of the reach of rain, until the amount of moisture is reduced to a satisfactory minimum, after which it is farther dried out artificially and sold in this form, or ground and compressed into briquettes.

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[1] Utilization of peat on a large scale. Engineering, May 12, 1905.

Many forms of drying apparatus have been devised and patented, and some are regularly manufactured for use in artificially drying peat, and the last stages of the drying can be done in these cheaply, quickly, and very satisfactorily..

One property which peat possesses, in common with other matter of vegetable origin, is its power to rapidly take up moisture from the air, after it has been thoroughly dried (to 2 or 3 per cent of moisture, until it will have almost as much water as it had in the normal air-dry condition, 15 to 20 per cent, about as soon as it is cold.

This is shown in the following table, which is the result of a series of tests made in 1904 upon peat of several different types, by L. Kirschbraun, at that time analyst for the Michigan Geological Survey:

No.	Peat.	Sample wet, gr.	Dried.	Wt. dried.	Moisture, per cent.
1	Jackson bog	5.0036	100=110°	.7339	85.33
2	Jackson bog	5.1971	over H. SO_4	.7709	85.17
3	Jackson bog	5.1447	150°0 C	.7213	85.98
4	Capac Peat Co	4.7013	100=110°	.5173	88.99
5	Capac Peat Co	4.7350	over H_2SO_4	.5081	89.25
6	Capac Peat Co	5.9224	150° C.	.5418	90.86

No.	Exposure.	Wt. after 12 hours.	P. C. gain.	24 hours.	P. C. gain.	36 hours.	P. C. gain.	48 hours.	P. C. gain.	72 *hours.
1	Sat. Atm. 34°C			.7811	6.29			.7832	6.73	
*2	Sat. Atm. 19=26°C			.8817	14.39			.9127	18.92	.8848
3	Open air	.8099	12.28	.8296	15.01	.8163	13.17			
4	Sat. Atm. 34°C			.5399	4.34			.5409	4.56	
*5	Sat. Atm. 19=26° C			.5606	10.33			.5740	12.96	.5605
6	Open air	.5821	7.44	.5977	10.32	.5814	7.31			

* Per cent gain 72 hrs., No. 2, 14.77.
No. 5, 10.33.

Nos. 3 and 6 were exposed during a rain storm between 12 and 24 hours.

The Jackson specimens were very dark colored, fine grained and compact; those from Capac bog, dark brown and of rather coarse texture. The gain in moisture at the end of 24 hours in all of these specimens was sufficient to make a considerable change in the heating value of the samples, and shows the inadvisability of carrying the process of driving off the moisture below 15 or even 20%, except possibly from very black, finely divided types, which show experimentally that they only absorb a limited amount of water after they are once dried thoroughly. The same analyst tested the moisture content of a sample briquette made at the Capac factory, which was reported, when made, to contain but 3 per cent of moisture. It has been kept in a dry room constantly from the time of making until analyzed, but was reported as follows: Capac briquette, moisture, 14.75 per cent.

Because of this property, it will be seen that it is not necessary to go to the expense of completely drying the peat to be made into briquettes, unless the process is one in which the dry peat runs directly from dryer to briquetting machine, and in which the briquettes are coated with a layer of tar at the time they are formed, for if the dried peat in uncompressed form is exposed to moist air while in storage bins, it will almost immediately absorb water from the air to the extent of 10 or 15 per cent. If, on the other hand, peat after complete drying, is compressed immediately, without water-proofing, and the briquettes thus formed are allowed to stand in the air for a time, it will be found, upon analysis, that moisture has been taken up by them from the air, just as it was by the uncompressed peat. That is, even briquetted peat is hygroscopic, actively taking moisture from the air, so that it is useless to dry it much below the air-dried condition of the peat, since in the end it produces no appreciable good results, and entails expense for drying which is relatively high when compared with that of reducing to the air-dry state. It may also give the retailer a marked advantage in handling freshly briquetted peat, in that it enables him to buy the product with a low moisture content and sell it after it has taken up 8 or 10, or more, per cent of water, although this may not more than compensate for shrinkage due to breaking and crumbling of the briquettes in handling.

It is apparent, from what has been said of the peculiarities of peat, that the manufacture into briquettes in large quantities and in such a way as to produce a steady output throughout the year, is not as simple a matter as it would seem at first thought, and while there are in Russia and other European countries numbers of large factories which do produce them, and which seem able to do so with a satisfactory margin of profit, the questions relating to entirely satisfactory processes are not yet settled, and new and improved methods of production are constantly being proposed. Russia is reported as producing annually 4,000,000 tons of peat briquettes, and as receiving $938,000 for leases of peat deposits. Germany produces more than 2,000,000 tons, and Holland and Sweden each more than a million tons of this type of fuel each year.

Assuming, then, that peat can profitably be made into briquettes, there are two types which can be made from pure peat, besides those in which other combustible material is mixed with the peat before compression. The two types in somewhat common use are cold-pressed briquette and the seared briquette. In the first, the peat is dried, ground, and then compressed by hydraulic or other heavy pressure, since no cementing material is used, in a specially constructed molding press, into blocks of a given size and shape, which will be easy to handle and burn. These blocks, which may be cylindrical, egg-shaped or prismatic, with, or without, rounded corners, are not covered with any moisture-proof substance, but have a slightly polished surface due to the pressure of the mold, and, when wet, absorb moisture readily and swell up to the original bulk of peat and disintegrate if allowed to remain moist, as well as break down rapidly when burned, thus, in part, defeating the purpose of molding it. They are also liable to show cleavage planes when examined closely, where the larger fragments of the coarse peat have arranged themselves at right angles with the direction in which the compressing force is applied, and it is quite easy to break them apart along these planes so that they must be handled somewhat carefully, and be transported and stored so that they will not get wet or very moist.

On the other hand, they form a good heating and steam-producing fuel, which burns rapidly without smoke, and has a high calorific value, having lost considerable of its volatile matter by heating, in the processes of preparation and briquetting. It is for the production of this type of briquettes from peat, that several companies have built plants in Michigan.

In the second type, the "seared" briquette, the peat is first pressed into hard, dense, blocks by the presses, after having been put through about the same treatment as in the cold pressed method, and then the blocks are heated sufficiently to free some of the tar and tar oils, which appear at the surface and form an impervious coating, preventing the absorption of moisture. This covering, also, gives a dark, smooth, oily or varnished appearance to the block and make it dense in texture on the outside. Not only this, but the varnish of tar has a certain cementing power to make the block resistant, and also brings the most easily ignited part of the block in contact with the fire. It is said that the briquettes of this type are slightly less rich in volatile matter than the cold pressed forms, but that they have nearly the heating value of hard coal and do not crumble in the fire as do the other types of blocks. These may be used for any purpose where hard coal or any smokeless, very efficient fuel is required, as they burn readily in grates, heating-stoves, and furnaces, kitchen ranges, and steam boilers, giving a flame somewhat like that of wood, and a strong heat from the time the fire is kindled, while, because of the density of the blocks they hold their shape until consumed. In all forms of briquettes the combustion is so complete that none of the free carbon or unconsumed gases escape into the open air, so this form of fuel has a considerable economic advantage over either soft or hard coal. A large plant at Whitewater, Wisconsin, and a smaller one at Bancroft, Michigan (closed), have been established for the manufacture of this type of briquettes.

So much has been said in other parts of this paper regarding peat coke and peat gas that little need be said here.

The following analyses published by the Prussian Board of Trade and Agriculture, show the ultimate composition of Peat Coke I of the Ziegler process as compared with charcoal.

	Peat Coke I.	Charcoal.
Carbon	87.8% — 86.0%	87.6%
Hydrogen	2.0% — 1.9%	3.1%
Nitrogen	1.3% — 1.3%	0.4%
Sulphur	0.3% — 0.3%	0.3%
Oxygen	5.5% — 5.2%	4.7%
Ash	3.2% — 3.0%	0.9%
Water	0.0% — 0.43%	3.0%
	Fuel value=7,800 calories 14,800 B. T. U.	Fuel value=7,800 calories 14,500 B. T. U.

Analysis of Peat Coke II.

(According to the Royal Chemical and Technical Experimental Station in Berlin.)

Carbon	73.89%
Hydrogen	3.59
Nitrogen	1.49
Oxygen	14.52
Sulphur	0.20
Ash	2.50
Moisture at 105° C.	3.80

Fuel value, 6,700 calories
12,450 B. T. U.

The fuel value of the coke is high, as is shown in the comparative table given above, and it differs from the other forms of peat fuel in having little volatile matter, this having been driven off by the process of distillation. This gives to coke the characteristics of charcoal in its combustion and it burns with little flame and no smoke, and when once thoroughly started, with intense heat, the temperature reached through its combustion being higher than that obtained by using any grade of coal. For this reason it might, as Hess has suggested, be useful in cement-burning rotaries. It is a clean, free-burning, smokeless fuel, easily handled, has small ash content, contains no substances which will injure boilers or furnaces, and, under forced draft, will give a very high temperature. It is especially adapted to all metallurgical processes where ordinary coke and charcoal are now used. But for its cost and scarcity, there is no fuel more satisfactory.

The quality of peat which yields the best coke is that rather low in ash, which will easily compact itself into a firm, dense block, after it has been ground and worked into a plastic condition.

It is reported that, in Russia and Northern Germany, peat coke is used to some extent for firing locomotives, and that it is so satisfactory in that use, that the Russian government is now making and storing it for emergency uses upon important railway lines. At present this form of peat fuel cannot be expected to compete, on a large scale, with coal in this country, but it could be used wherever charcoal is used, and, as has been suggested, it might find extensive use in metallurgical operations, especially in blast furnaces, for the manufacture of charcoal iron as a substitute for charcoal prepared from wood.

It thus becomes apparent that the preparation of peat for fuel in such form that it is easily transported, and approximately equals in heat-giving power the efficiency of the other fuels with which it must be compared, and with which it must compete, is no simple matter; that with each increase in compactness, portability and calorific power, an additional treatment must be given it, requiring more complicated and expensive machinery than the processes giving the less compact forms. In these more extended and elaborate forms of treatment, if they are to return a profit, the processes must be largely automatic and continuous, doing away with human labor as much as possible and depending largely upon well-planned and carefully placed machinery, which must be capable of handling, grading, and preparing large amounts of heterogeneous crude material, rapidly and cheaply and of turning it into the maximum amount of marketable and efficient fuel. If this can not be done, then it is better to hold to the simpler forms of machinery which are easier to operate, and very much less expensive to buy, and with these, to make a smaller amount of the compressed, air-dry fuel, and supply small and perhaps purely local markets, with a fair margin of profit and success.

As Affected by Cost of Preparation: The cost of preparing peat fuel for market is, of course, governed somewhat by the extent to which the preparation is carried, but in the more elaborate methods the cost is increased by the necessary charges for maintenance of the expensive plant, as well as for the more numerous operations, so that while cut peat, air dried, may be produced for less than 50 cents per ton, the cost of producing a ton of peat coke, having about double the number of heat units, is 5 or 6 times as much, $2.50 or $3.00 per ton, at the German mill, to which must be added the cost of selling, transportation and handling. The cost of preparing the briquetted peat is given by various writers as ranging from 1 to 2, or even 3, dollars per ton, and probably would exceed the latter figure in many cases where errors were made in planning the plant. It should also be considered, that the situation, and especially the mechanical condition of the peat, affect the cost of production, and it is only the best adapted and most uniform beds which can be made to produce a uniform and satisfactory product. It is probably true that it will be found, when all things essential are taken into account, that the cost of making briquettes of peat which will stand transportation and other tests satisfactorily, will not be below $2.00 per ton at the factory, and that this cost will be much exceeded in very many if not the majority of cases.

Conclusions: It may also be well to call attention in this place to statements frequently made by advocates of the simpler methods of treatment of peat, that compressed peat is the only form in which the material has continuously and successfully been placed upon the markets abroad, and that while the briquetted form is made and sold, that it is not a commercially successful article even in the best European markets, as yet. These statements are in part, at least, substantiated upon a report on peat utilization in other European countries to the Norwegian government made in 1903, and quoted by the U. S. Consul-General[1] to Norway in a report to the home government, in which it is stated that "Common hand or machine made peat is acknowledged to be the most promising article."

So much of the literature relating to this question is of the nature of advertising, or booming matter, that it is not easy to be certain as to all of the statements which are to be found in print, even in places where reliable statements would usually be found, hence the apparent contradictions appearing in this summary.

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[1] Bordewich, Henry, Special Consular Reports, Volume XXVI, p. 119, Washington, 1903.

MACHINERY FOR THE PREPARATION OF PEAT FUEL AND PEAT LITTER.

In previous sections of this paper, various stages of the development of the manufacture of peat fuel have been discussed, and the underlying causes which have brought about the extended experiments have been briefly considered, and in this section a short account of some types of machinery for the gathering and preparation of peat for fuel and other uses will be given, and in addition, the names of a few manufacturers of similar types from whom illustrations, catalogs and other information relating to their machines may be obtained. It is not intended to make this a descriptive catalog, but simply to show how the machinery for the preparation of peat for fuel has grown in complexity and efficiency as the experimental work of inventors and investigators has gone on.

The Slayne or Slane as Used in Different Countries.

The earliest tool used in preparing peat for fuel, and one still in use, even where machinery has been introduced to perform the same work, is the slayne (Plate XXIX), or slane, a modified spade, with a blade nearly or quite two feet long and from 4 to 6 inches wide with a projection or flange 4 inches long and 5 inches broad, at right angles to the blade, having a sharp edge, which cuts the side of the block. This tool may be made wholly of iron or steel, or of wood, with steel cutting edges. The surface of the peat is first stripped of plants and the coarse and partly decomposed plant débris making up the top layers, which are unsuitable for manufacture, by the use of ordinary tools used in clearing land, and straight ditches, with perpendicular sides, are dug for drainage. When the usable peat is exposed, the workman cuts into it with his slane, tears a block of it off from below and lays it out on the surface. The blocks may be 5 or 6 inches square on the ends and from 15 to 18 inches, or even more, long. Such blocks will weigh, as cut out, from 12 to 25 pounds apiece, according to the amount of water present, and the degree of decomposition of the peat, and a skilled man, used to the work, is said to be able to cut sufficient material to keep two teams busy drawing it away, since he only cuts the peat and places it on the surface of the bog beside the trench from which it is taken, the loading being done by helpers. In South Germany the workman stands upon the surface of the peat bed, which is from two to four yards broad, and makes vertical cuts, while in Middle and Northern Germany, the horizontal cut is more commonly used. In these regions, one workman cuts or marks out the blocks, with perpendicular strokes, beginning at the outside edge of the cleared space, and a second one cuts them off the bottom with horizontal strokes, using a specially constructed spade, and lifts the blocks up and lays them to one side, on the ground, to dry.

In Ireland, it is said, that the vertical cut is generally used, the blocks being lifted by the cutter to the side of the trench made in digging them, whence they are removed after they have somewhat dried, or they are taken green to a more favorable spot, a good workman keeping two helpers busy moving the blocks, or sods.

The only preparation given hand-cut peat is to dry it by exposure to sun and air, generally upon the surface of the bog, but since rain causes the freshly cut blocks to break down quite readily, they are sometimes protected by rough shelters for a time, the blocks being frequently turned over to insure thorough drying on all sides. After the blocks have been dried for a time the surface is much less readily penetrated by water, than when they are first cut, and they may then be exposed to the weather with little or no damage.

In parts of Europe, in extensive hand cutting of peat, the workmen are employed in gangs of five, one who clears the surface of disintegrated and worthless peat, two cutters, who cut and lift the blocks from the trenches, and a loader, who picks up the blocks left by the cutters and piles them upon wheelbarrows, and the man who wheels the loaded barrows to the drying ground, usually the cleared surface of the bog on one side of the trench, which is smoothed up for the purpose. The peat is turned from the wheelbarrows onto this space and left to drain and dry for a time, after which it is taken away and piled up in rows, each row being allowed to dry, in part, before another one is placed on top of it. Usually the blocks are left here to dry for about a month, during which time the water content is reduced about one-half, and then are piled up in store houses, or in large stacks, to be more fully dried. The stacks are usually built up on the higher parts of the bogs themselves and after the blocks are thoroughly air dry, they are carted away to storage.

In the bogs where the peat is too wet, and soft, or too uneven, and irregular in structure, to permit of its being cut into blocks, it is either lifted in nets or dredges, as in Holland, and parts of Germany, or dug up in small blocks, which, after being drained, somewhat, are trampled under foot until ground up and rendered even in structure, and then cut into pieces and pressed into molds with the hands like brick clay. Peat treated in this way, is more compact, and therefore better fuel, than ordinary cut peat.

Machinery for Making Cut Peat.

Machinery for cutting peat from the bogs was one of the earliest forms of improvement which was made in the process of making peat fuel, and it is stated that a machine for this purpose was invented in France, as early as the middle of the 18th century, and not much later, machines were in use for cutting peat in Germany, to a limited extent.

A typical peat cutting machine, used at the present time in various parts of Germany, and extensively advertised, is the Brosowsky machine (Fig. 19) made at Jasenitz, which was first introduced in 1843, since which time it has been much improved, and of which the manufacturers claim they have sold over 8,000. By its use, peat can be cut and raised from a depth of 20 feet, or more, below the surface whether covered by water or not, hence wet bogs need not be drained, but may be cleared of peat without trouble, or those which have been worked as far as possible with hand labor, may be still further worked by this machine. The essential part of the machine is the cutting apparatus, which consists of a set of three knives, forming a box open at top, bottom, and one end. This three-sided knife is fastened to the back of a wrought iron bar, by means of which the knife is forced into the peat. The bar is operated by a rocking pinion, and a shaft and crank. By turning the crank, the cutting apparatus is moved up and down, and with the weight of the knife as it is lowered, the cutter may be forced into soft peat as much as 36 feet, but it should be noted that the machine can only be used at the side of the hole where the peat has been taken out.

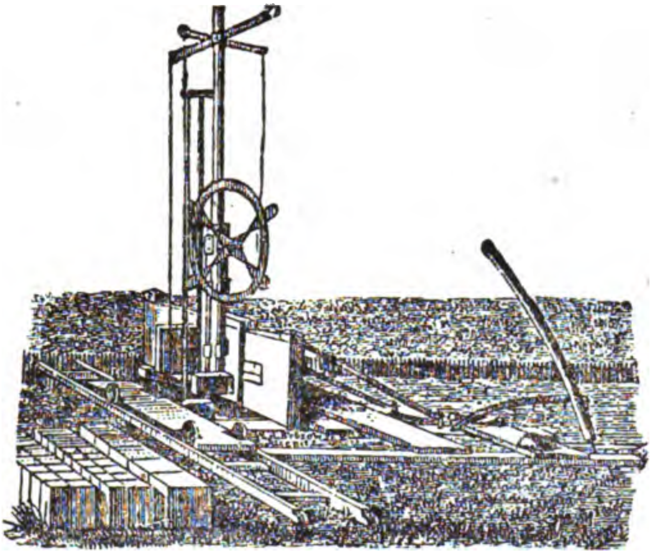


FIG 19. Machine for cutting Peat.

As the cutter has three sides of the block of peat to cut, on the side where the bar is fastened, there is fixed a sharp, flat knife, the purpose of which is to cut off the form or prism of peat made by the downward passage of the large three-sided knife. This cross-cutting knife is provided with two chains which pass over two cylindrical rollers, and by means of two levers, may be turned backwards or forwards. When the cutting apparatus is drawn up by means of the rocking pinion, this knife at the base holds the column of peat in place, since it forms the bottom of the box, and there are guides to prevent the column from falling over, which it might easily do, as it has a height of 3 to 6 yards, and base of 24 by 28 inches. After one block of peat has been taken out, the cutting apparatus is moved its own breadth sidewise on a frame. This frame is of such width, that 4 cuts may be made side by side befóre the machine has to be moved back the width of the knife. To aid in the backward movement, one side of the three-cornered frame supporting the apparatus is fitted with two small wheels which fit into a groove in the supporting timber and lie underneath it. By means of a projecting level, the machine is started upon the two wheels and is then moved back by another level which fits into holes in the underlying beam. The price of these patent machines varies according to the depth to which the cutter can be forced, from about $110.00 for 2 yards, to $145.00 f. o. b., for 6 yards.

Two men can cut about 3,000 cubic feet of peat with one of these machines in 10 hours, and with two helpers can produce from 10,000 to

12,000 blocks 8 inches long and about 5 inches square at the end, including the arrangement of these in rows upon the drying floor.

Another cutting machine which is in somewhat general use in Europe is that made by C. Muller of Dominion, in Pomerania, which is recommended for use under water and is also said to be capable of digging deeper than other similar machines. This cuts and lifts the peat in a cylindrical form from 2 to 6 yards high, according to the thickness of the layer. It is so arranged that four columns of peat can be cut without moving the machine. When the cutting cylinder is pushed down to the desired depth into the peat, the column is cut off by a knife, operated by levers, and this knife also holds the peat in the cylinder by forming a bottom for the cutting tube. As the cylinder with the column of peat is raised by one man, a second workman, with a spade, cuts the column into pieces of uniform length, and lays them on a car, by which they are carried to the drying floor, after which they are cut into smaller blocks and arranged for drying.

A third peat cutting machine is that made by Karl Weitzmann at Greifnagn, which cuts the peat to a depth of four feet into rectangular columns, which are then drawn to the surface and divided into cubical blocks as before.

Another German machine of similar type is that of R. Dolberg of Rostock, Germany, German patent 43106, but, while it is an efficient machine, it is not necessary to describe it here.

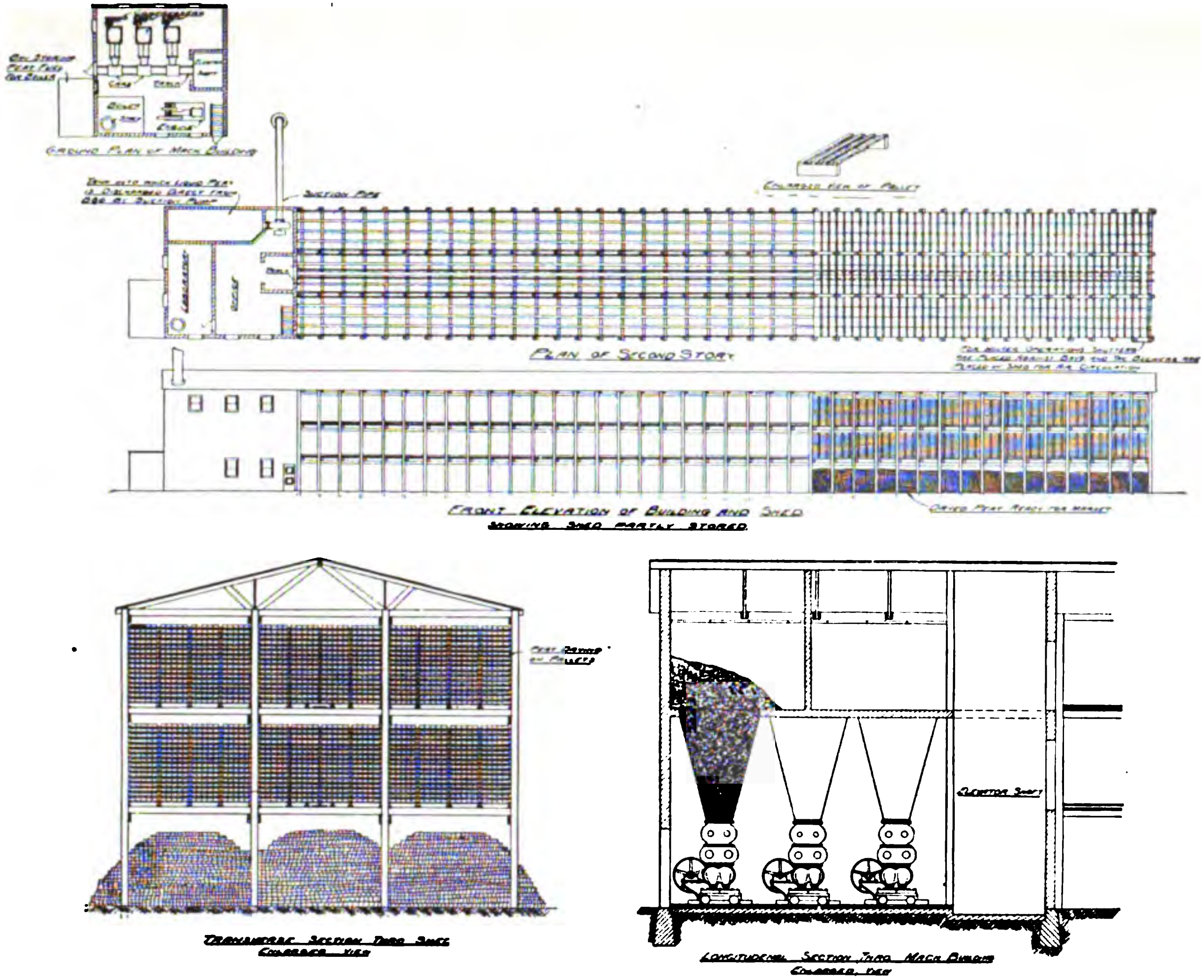
Of digging machines, which simply dig the peat from the bogs from a greater or less depth from the surface, and convey it by mechanical means to carts, cars or presses, and which are usually considered as essential parts of the outfit necessary to make compressed peat on any but the smallest scale, may be had in a variety of forms, to be run by man, horse or steam power, at prices ranging from less than $50.00 to several hundreds. They do not cut the peat into large blocks of regular size, but are constructed for the purpose of removing the material rapidly from the bog and giving a constant and sufficient supply to the presses or other machines used with them, at small expense. These diggers according to claims of the makers, may be used down to depths of 25 feet, or more, below the surface, and are operated by a series of Archimedian screws, or may consist of an endless chain of small shovel-shaped buckets, each of which takes a small load of peat as it rises and carries it to the top of the elevator and drops it, much as the buckets of a grain elevator work.

Machines for Making Pressed or Condensed Peat.

It has so frequently been pointed out that cut peat is bulky and fragile, as well as indifferent fuel, and that its efficiency and other desirable qualities are improved by compression, that it need not be discussed again here. The simplest process to improve the quality is compression or condensation, the latter being the better term, since very little actual compression is used by the machines producing this sort of fuel. As the result of the treatment by the more improved types of machines, about one-third of the bulk of the peat is lost, and when dry, it becomes hard, firm, nearly waterproof and is increased in efficiency as fuel.

Mention has already been made of the treatment of soft, or very coarse

Geological Survey of Michigan. Annual Report for 1906. Fig. 20.


Ground Plan of Mach Building
Suction Pipe
Laboratory
Office
Plan of Second Story
Enlarged View of Pallet
Front Elevation of Building and Shed
Showing Shed Partly Stored.
Dried Peat Ready for Market
Peat Drying on Pallets
Transverse Section Thro Shed
Enlarged View
Elevator Shaft
Longitudinal Section Thro Mach Building
Enlarged View

PLAN AND SECTION OF PEAT FACTORY.

peat, by which it was shaped in small molds by hand pressure, and the earliest methods of machine compression were not much more elaborate than this, since the early forms of press were simple rectangular boxes, with a close fitted piston, which could be pushed down into the box by screws or levers, holes being provided for the water liberated by the pressure, to run off. Compressed peat was made in Saxony, as early as 1820.

Later machines show development along many lines, but in addition to mere compression, most of them grind, or roll, the peat and subject it to a kneading process to break up the vegetable structure of the plant remains in it, in order to make it easy to get rid of the air and water which may be entangled in the cavities of these structures. Some of these machines have combined rolling, cutting, and filtering through coarse cloth, as the Mannhardt and Koch press, described by Percy[1] as follows:

"The principal feature of this press consists in the use of a pair of large horizontal rolls covered with cloth to serve as a filter. On the circumference of the roll, ribs of hoop iron are fixed obliquely about one inch apart, which support drilled iron plates surrounded by an endless band of cloth. The wet peat is torn to pieces and put in two hoppers, one over each roll, whence it is drawn by rake rollers; but in its course to the large rolls it passes through a series of three small rolls, fixed above each large roll, whereby it is deprived of most of its water. There are thus two streams of peat descending from the two hoppers and passing, first through a pair of small rolls, then through a pair of spiked rolls and lastly through the two large rolls by which the remaining water is pressed through the remaining filter-cloth into the interior of these rolls. The peat now forms a compact sheet which is conveyed to a knife-like apparatus, which divides it transversely, and then to circular cutters, which divide it longitudinally into blocks of the required dimensions. The peat is thus freed from water to such an extent that its further dessication may be effected in favorable weather, in the course of a few days, under covered, airy sheds, or in unfavorable weather, by artificial heat in suitable apparatus."

The same writer describes a number of other forms of presses, some of which are still in use, having been improved from time to time up to the present. A good peat-pressing machine must be simply and strongly built, must run easily and without requiring excessive repairs and should be built so that it can be moved from place to place readily. It must do its work quickly, grind and mix the peat thoroughly and deliver the blocks well formed and of uniform hardness, which, however, need not be very great. The peat should be easily fed to it and the completed blocks readily removed to the driers.

There are machines meeting all these requirements now manufactured in Germany, in this country, and in Canada.

One of the most generally used machines of this kind in Europe, is that made by C. Schlickeysen of Rixdorf, near Berlin, which has been mentioned already. This machine first appeared about 1860 and has been constantly improved until the present time. A late pattern has an excavating machine which cuts the peat from the bogs, when not too full of logs, stones, etc., and delivers it by means of a long, sloping belt-and-bucket elevator, into a cylinder, in the axis of which a shaft revolves, carry strong, projecting blades, which have cutting edges and which are arranged spirally, so that they force the peat along. The blades are nearly, but not quite, in a true spiral, so that they act unequally on the peat, thus grinding, cutting and mixing it, the more perfectly. There are no projections or blades on the inner surface of the cylinder and the finely divided and condensed peat pulp is finally forced out by a horizontal screw, in the form of a continuous flexible, prismatic, block, 3 by 4 inches in section, at the tail of the machine, where it is received on boards 3 feet in length, which, as soon as filled, are loaded onto small cars and run out to the drying grounds, where the blocks are laid out in rows and cut with a knife into bricks, 10 inches long, and left to dry. They lose in ordinary weather one-half their water content in a period of two weeks, after which, they may be quite profitably dried artificially, or be left for a longer time exposed to the air. By the use of this type of machine, the peat is reduced one-third in bulk, so that a machine handling 21 cubic yards of raw peat per hour, delivers only 14 cubic yards of condensed peat in the form of bricks, or blocks, 10 inches long, by 3 by 4 inches in section, and weighing when dry, from 2½ to about 4 tons, in which condition it is good fuel, hard and tough and easily kept dry. A plant of this kind includes besides the excavator, elevator and grinding press, a 10-horsepower portable engine, which uses peat refuse for fuel, and cars and tracks for removing the blocks from machine to dryer, etc. Since the whole plant is portable, it may be placed on the further side of the bog to be worked and moved backward as the peat is taken out. The cost of such a plant complete, is about $5,000, ready to operate and its operation when used without machine or digger, takes 19 men including the engineer and fireman.

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[1] Percy, John, Metallurgy: Refractory materials and fuels, p. 231, London, 1875.

Horsepower peat machines for compressing peat are manufactured by a number of European makers, among which is that made by R. Dolberg, which requires to run it, a good stout horse, 6 men, and a boy to lead the horse. The machine is placed about 8 yards from the edge of the peat bed, with the opening to the press turned toward the bog, so that it may easily be reached. In operating this machine the horse is hitched to a traction beam about 18 feet long and 4 inches square at the smallest end, and if the ground is soft a board or plank track must be laid, or broad shoes, such as are used in gathering marsh hay, fitted to the horse's feet. The peat is dug by hand and thrown into irregular piles, from 25 to 50 feet broad, according as the peat is deep or shallow. The digging requires one man, and a second wheels the peat to the machine, which is fed by a third, who is general foreman and especially has to see that the horse keeps up a uniform gait. A roller is fastened under the mouth piece, in the same direction with it, to receive the finished peat as it comes from the orifice of the machine, hence the roller must be more or less inclined according to the consistency of the peat, so that the manufactured blocks may neither choke the machine nor be torn apart; the rollers must be adjusted high enough so that the peat table rolling on them stands about 4 inches from the mouth-piece.

The boards on which the condensed peat is received, are placed on the rollers and the peat block is cut into bricks with a knife as it comes out. As fast as the boards are full, they are lifted into a cart, and when the cart is loaded, it is driven off to the drying ground by two other workmen, who unload and arrange the blocks upon the ground. In this work, two-wheeled carts, taking about 16 boards of 10 blocks each, and running on board tracks, are used. The wheels of the cart are so placed that the weight of the peat balances the load and makes the work of pushing them easy.

The machine itself, consists of a revolving, spiral cutter and is enclosed in a stout, iron casing, with a hopper-like opening at one side near one end, and the opening for the condensed peat at the other. If, at any time, the spiral, or the mouth piece is stopped by pieces of undecomposed wood, sods, stringy material, or too dry peat, it can be cleaned through openings in the side of the casing, provided for this purpose, or the mold and mouth-piece may be opened and the cause of the trouble quickly found and removed.

If the horse is to work the machine easily and satisfactorily, the peat should be put into the machine so wet, that when the blocks are cut off at the tail of the machine, they will be only sufficiently solid to hold their shape on the board. This is contrary to the belief of inexpert workers, who think that the peat should come from the machine dense and solid, but a much larger and more satisfactory output can be obtained by working the peat wet, and the drying goes on about as rapidly, since the grinding and kneading increases the capacity for drying and contraction so that in 2 weeks of good drying weather, the bricks can be piled.

With the horsepower machine, the chief points to look out for are that the horse keeps going steadily and that each man keeps up with his special part of the work and the duty of the man who feeds the machine, and who is also foreman, should be to see that the horse keeps an even gait. If this is done the quality of peat blocks produced is uniform and each set of men has to be prompt in bringing up the raw material and in taking away the finished blocks. Where this is done, and especially where the work is paid for by the thousand it is not hard to get a production of from 14,000 to 16,000 bricks per day with a single horsepower machine. When in use, and peat has to be brought more than 75 steps, the machine should be moved to a new spot nearer the supply.

In the Heinen horsepower machines made by A. Heinen, Varel, Oldenburg, Germany, the essential parts are a vertical cylinder firmly attached to a timber base, in which is the grinder and condensing apparatus turned by a long beam at the top. At one side of the cylinder near the bottom is the delivery spout, so that boards for the reception of the finished product can run in it. The peat bricks made by this machine are about the size of those made by the others and are handled in much the same way. The manufacturer estimates from 8,000 to 10,000 peat bricks per day with one horse, as the capacity of this machine.

Another manufacturer of machines for making condensed peat, is Weitzmann, who makes a machine which may be either used by horse or steam power, and which is said to work all kinds of peat without difficulty. This consists of a horizontal cylinder, somewhat larger at one end, where the hopper is placed, than at the other, or outlet, end. On top of this smaller part, is a short transverse cylinder of about the same diameter. In the long cylinder is a long axis turned by a fly wheel geared at right angles with it, upon which is bolted a series of powerful steel blades arranged spirally, so as to give a forward motion to peat while cutting it and in the upper cylinder is a deeply corrugated roller, the depressions of which fit over the blades of the cutting apparatus, and materially aid in reducing the peat to a finely divided state. The pulp is pressed forward to the tail of the machine and out through a pipe, where, as in other machines, the block is received on a moving table and cut up, and taken away to be dried.

Peat presses are also made by G. Traskatis, Lyck, East Prussia, and Stutzke Brothers, Lauenberg, Prussia. Of American made machines which make condensed peat, the best known, and longest used is the Leavitt Peat Machine (Plate XXXI), invented by T. H. Leavitt, recently deceased, who became interested in peat fuel manufacture about 1865. This is a machine operated by steam power, in which it is designed to break down the vegetable tissues and cells in the peat, liberate the air and water contained in these, and thus render the material plastic, so that it will become compact and hard when dried after slight compression. The machine may be considered in two parts, the condenser, and the molding mill, which are separate but connected by a belt conveyor, and which together occupy a space 6 x 10 feet on the floor and 10 feet high, exclusive of the engine and boiler.

The condenser has a revolving cutter or "ripper" consisting of a series of spirally arranged knives on a small shaft just below the hopper, where it receives the crude peat and cuts and tears it to pieces. From the ripper, the peat enters a series of three pairs of cast iron rolls, each three feet long, with the lower roll of the first pair heavily corrugated to help move the material along. These rollers perform a rubbing or grinding process which is brought about by a different rate of rotation for each roller of each pair. The upper roller of the first pair makes 40 revolutions, to 20 of the lower; the upper one of the second pair 90, while the lower one makes only 40, while in the third pair, the upper one revolves 180 times while the lower one turns 60 times. After passing through these rolls, the peat, finely divided, and deprived of most of the air which it originally contained, has shrunk in bulk from 30 to 50 per cent, and has about the same amount of water it had to start with. It is then in a pasty condition, and is received by the belt conveyor, which is enclosed in a wooden casing, and carried to the hopper of the molding machine. This is an upright cylinder supported upon a heavy cast iron base nearly five feet high; below the upright part is the molder, or press proper, consisting of two horizontal revolving cylinders, which are similar to the molds of brick making machines. Below this is a table made up of boards supported by a belt carrier, which receives the peat bricks as they come from the machine. The upright cylinder contains a series of semi-circular shelves, arranged alternately on opposite sides of the chamber, and each with a series of radial slots one-half inch wide. A central shaft, carries, just above the shelves, a corresponding set of two-armed sweeps and a less number of single-armed ones. The former rubs the peat against the shelves and the latter help to press it down into the pockets of the molding cylinders, from which it is forced by plungers onto the boards of the table below in the form of blocks or bricks, 4 by 8 by 2½ inches. The capacity of the machine is 108 blocks per minute, or about 65,000 per 10 hour day, which, after drying, amounts to about 40 tons of good hard fuel. The blocks taken from the machine may be conveyed to the drying grounds or sheds by any convenient way, and may be spread out in rows or piled in racks, and left to be dried by the wind and air. The wet blocks commonly weigh about 3½ pounds, contain 80 cubic inches, and have a surface of about a square foot. The blocks shrink as they dry, and get to be nearly as hard as stone and impervious to water, the drying taking from four days to 2 weeks, according to the weather, when they are ready for the market. A plant using this machine is in operation at Orlando, Florida, where it makes all the fuel used by the Orlando Water and Light Company which develops 500 horsepower. The capacity of the peat molding machine can be increased by increasing the speed, trial runs showing that it can produce as much as 400 tons per day without difficulty. The cost of putting up a plant equipped with this machine is figured at $5,000, divided as follows:

Machine	$1,500
One engine and boiler, 12 horsepower	1,500
Shafting, belting and fixtures	500
Roughly constructed building	1,000
Incidentals	500
Total	$5,000

The cost of labor is also a very important item, which must be taken into account in considering the possibilities of manufacture of peat fuel. With this machine using 100 tons of crude peat per day, four men will be required to cut the peat from the bog and load it on cars; a boy with a single horse, and two cars running on a tramway, can handle the transportation to the mill. One man is needed to feed the mill, one to put molds into the mill, two to take the molds from the mill, a boy, one horse and three trucks to transfer the molds to the drying ground, two men on the drying ground to empty the molds, a boy to take the molds as they come back from the drying ground and put them in the proper place, and engineer and superintendent. There will also be needed two or three men and a boy, with a horse, to care for the dry fuel and house it at the proper time. The men and horses should be hired for less than $40 per day, and except in very wet weather, should produce an average of 25 tons or more of fuel per day. The air drying makes the production somewhat uncertain, as in very wet or cold weather, evaporation of the water from the bricks is slow and uncertain, unless there are covered drying sheds provided, which will increase the cost of the plant somewhat. It is supposed that all steam for operating the plant will be generated by the use of waste material from the bog. The product from such a plant should sell at from $3.00 to $4.00 per ton, where hard coal is sold at about $6.00 per ton, and for more where it is higher. By increasing the number of machines the cost of production could be lowered materially by substituting mechanical devices for some of the hand labor.

There are numbers of other condensing and compressing machines upon the market abroad, a single maker sometimes advertising a half dozen types, ranging, in power required, from 1 to 50 or more horsepower, in productive capacity, from 5 to 50 or 60 tons of condensed peat per day, in price from $300 to $1,500, and in the number of men required to run them, from 7 to 25. All of the German makers mentioned above advertise some form of press for making condensed peat.

An estimate, given by Julius Bordollo, 38 Kingsbridge Ave., New York, agent for several of the large European makers of peat fuel machinery, for a plant having a daily capacity of 40 tons of condensed peat, is as follows:

To be imported from Germany.	1 peat press, latest design, with double breakers and mixers, mounted on wooden frame	$1,200
	1 chain elevator, 30 feet long, complete with rollers and shovels	950
	2 appliances with axles and wheels for moving press and engine	700
	1 cutting table	100
	100 feet of rails	250
	6 iron cars for transporting the peat to drying grounds	300
	18 horse-power engine	1,500
	Belting, boards, and sundries	100
	F. O. B. New York	$5,100

This estimate does not include the cost of buildings and installation of plant, but these need not be large, since the press and engine are portable and can be sheltered by a very small structure.

The cost of production per day, with this plant, is estimated as follows:

1 foreman	$5 00
1 engineer	5 00
8 laborers	12 00
5 boys	5 00
Office and selling expenses	10 00
Boiler fed by refuse peat and waste from bog	......
Total expense for 40 tons peat fuel	$37 00
Or cost per ton	92½

A rather low estimate, at the present prices of labor, and should be adjusted for each locality where a plant is to be established.

Machinery for Drying and Briquetting Peat:

The advantages and disadvantages of drying peat by artificial means have already been dwelt upon at some length, in a previous section, and no further space need be devoted to the matter here, except to again enforce the statement, *that no form of drier can take raw peat from the bog, and dry it by artificial heat, even to the air dry condition, except at a loss, unless the heat thus used is waste from some other industry or process.* It must also be remembered that where the peat is dried at high temperatures, it loses some of its volatile matter, which, by so much, may reduce its value as fuel for certain purposes.

Early attempts at drying peat made use of chambers, in which the peat was placed and subjected to drafts of heated air or other gases, sometimes forced into the bottom and sometimes at the top of the drying chamber, or kiln, by the use of exhaust fans.

Of different type is the Schonomen dryer, in which the raw peat is sifted, in order to extract from it the fibers, the non-fibrous part passing into a vat of heated water, where it is thoroughly mixed into a fluid mass or "slurry." From this vat it is pumped by slurry pumps, into a so-called chamber filter-press. As soon as the chambers are full, the slurry pumps are changed about so that they pump air instead of slurry into the filter chamber, and a high air pressure is produced, which can be raised to 20 atmospheres, 300 pounds per square inch. The compressed air drives out all the overlying water and about one-half of the original water contained in the peat, through the bottom of the chamber. The cakes of peat formed in the press, fall out when the chamber is opened, and are broken up and transported to drying ovens heated by steam, where the partly dry peat is quickly and thoroughly dried. The steam drying ovens can be heated by waste steam from the briquetting machine, which is used in connection with this process.

The Stabler process feeds the peat through rollers until it is crushed and ground very fine, after which it falls on a heating plate and is pushed forward by workmen to the farther end of the same plate, where it falls between rollers which grind it still more, and it is then conducted on intermediate heating plates back to the starting point. This process is repeated until the peat is sufficiently dry.

By the Stauber method, the peat is dried in the open air for a time, then dumped into conveyor pits to be conveyed to the condensing apparatus. The latter is a band of wire gauze of large mesh, which passes under two rollers. These press the peat against the gauze and the free water is pressed out. At the end of the gauze band, which is 5 feet wide and 15 feet long, an endless chain, provided with scrapers, causes the compressed peat to fall upon a kind of sieve shaker, which separates the larger pieces, the proportion of which should be as small as possible, and these are sent to be treated again by the rollers. The fibers and undecomposed vegetable matter which stick to the wire gauze are cleaned off by a revolving brush which runs below it. From the shaker, the finer peat is taken by a vertical conveyor, and is broken into small pieces in a special mechanism, as it passes along to the drying oven. This is a metal drum, 5 feet in diameter and 25 feet long, placed horizontally on rollers. The cylinder is rotated, and a spiral stirrer inside of it is used to push the peat forward, as it is dried by coming in contact with hot gases from a furnace. The cylinder is driven by a 50 horse-power engine, and the dried peat, after removal from the dryer, is crushed and briquetted. By this process, a ton of raw peat is reduced to about ¼ ton, containing about 100 pounds of water after it leaves the dryer, and is ready for the briquette press. Mention should be made of the tunnel type of drying chambers such as are used in drying brick in some of the modern brick plants. Selwid and Lange have patented such a chamber in Germany, patent number 22,223, and a similar device was used at the Jebsen peat coke plant in Norway. At the latter place the air-dry blocks of peat, loaded on cars, provided with racks of shelves, were run into the cool end of the tunnel and subjected to a gradually rising temperature, until they reached the warm end, where they are heated slightly above 100° C. The heat, in this case, was supplied by waste gases from the coking ovens, the dry, warm air being drawn through the tunnels by fans driven by electricity.

The Cooley dryer, recently patented in the United States, consists of a series of broad, shallow, galvanized iron pans, arranged one above the other in steps, in such a way that they can be given a rapid vibratory, shaking motion. The series is divided into two parts connected by a chain elevator and each is enclosed in a chamber, the first of which is heated by steam pipes and the second by hot air from a furnace provided for the purpose, and which burns the refuse material from the crude peat. The peat, air dried, or even wet from the bog, is ground by passing through toothed rollers, then elevated by a belt conveyor to the top of the first dryer where the coarse matter is screened out, the fine falling on to the top pan of the dryer, from which it is shaken to the one below, and so on, to the bottom one of the series, from which it is elevated to the top of the second set of pans and again passed down, this time subjected to a higher temperature, after which it emerges, with less than 3 per cent of moisture, in the form of a fine powder, and is conveyed either to the briquetting machine, or to storage bins. The whole process by this system of drying takes less than an hour, if the peat is air dry, and but little longer when wetter than this.

Machines for Briquetting: The great development of the manufacture of various kinds of fuel into briquettes has led to the invention of many forms of presses in Northern Europe, where coal slack and washings, lignite, or brown coal, coke, sawdust and peat, either pure or mixed with each other, or with petroleum refuse, pitch, tars and other binding material, are all made into briquettes by the use of pressure and heat. When the question of using peat for fuel in this country was raised a few years ago, the highly finished, regularly formed, compact and exceedingly neat, as well as efficient peat briquette, attracted the eye, as well as appealed to the imagination of those who decided to make an investment in the new fuel, and, as a result, most of the plants for the manufacture of peat fuel in America are briquetting plants, using, in some cases, foreign made presses and in others, specially invented machines.

It has already been stated that two kinds of briquettes are made from peat, the cold-pressed and the "seared." It may also be said that several types of presses are used for making the first kind of briquettes, of which the open and closed mold systems are the most important. The first of these gives large production, is easy to work and keep in order, and is simple in construction, while the second permits the use of higher pressure, hence gives a more compact product.

The open mold system has, as its basis, a tube, open at both ends, into one end of which, a piston fits, the other end being left open, and whose cross section is that of the finished briquette. The resistance produced by the friction of the peat in passing through the mold gives sufficient pressure to make compact briquettes. In practice, when a proper amount of material has been put into the mold, the piston descends and compresses it, then more material is put in between the piston and this briquette, the piston moves forward and forms a new briquette, and at the same time forces the finished one from the open end of the pipe. By this system, in practice no very great pressure can be used, as the amount developed is dependent upon the length of the tube and the friction of the finished briquettes against its walls. For when a long tube is used and the resulting high pressure, due to increased friction is obtained, excessive wear, due to heating and strain, causes rapid deterioration of the machinery. To give increased resistance, with short tubes so that higher pressure can be used, the tube is sometimes made to taper from the piston to the lower end. The machines in which the open mold type of press is used generally have the molds arranged in pairs, so that continuous motion may be obtained. This is reported to be the favorite form of briquette press in France and Germany and many modifications of it have been patented and manufactured.

The Dickson press used in the manufacture of peat briquettes at the Welland, Ontario, bog, is of this type, and, according to Carter,[1] in this press, for a mold or tube 2½ inches in diameter, a length of one foot will give a frictional resistance equal to a pressure of 8 tons per square inch on the piston. By the use of this type of mold, with the highest practicable friction, heat may be developed sufficient to liberate tar from the peat and give the briquettes a waterproof covering.

The closed-mold system is capable of many variations, but in one of the simpler forms, consists of a revolving table containing holes the shape of the briquette, but deeper than its smaller diameter. In operation, the holes properly filled, are passed in turn under a powerful hydraulic press by the revolution of the table, and the briquettes thus formed are then immediately thrown from the mold automatically.

In another form, the material is compressed simultaneously by two pistons forming the top and bottom of the molds, and in still another the molds are formed by depressions in rolls or wheels, which revolve either vertically, horizontally, or in a more or less inclined position. Where rollers are used, the product is frequently in the form of balls or egg-shaped masses, which are known as "boulets," or bullets, in France, where various types of coal waste are commonly sold in this form.

The Dobson press, used at the Beaverton works at Beaverton, Ontario, is of the closed mold type, the bottom of the mold being formed by a block of metal, and the molds are arranged in groups of 8 under each of the two compressing pistons which work reciprocally, and each time the piston is raised, the mold cylinders turn one-eighth around. With each down stroke the piston forms a briquette on top of one which has been made by a former stroke of the same mold, thus compressing it a second time to make it as compact as possible. The power used with this press is furnished by a steam engine and the mold cylinders make about 50 revolutions per minute, making about double that number of finished briquettes.

The cost of briquetting machinery is higher than that for making condensed or cold compressed peat, and ranges in average price from $10,000 or less, for plants of small capacity, 25 tons or less per day, to

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[1] Carter, W. E. H., Peat Fuel, Its Manufacture and Use, pp. 23-25, Ontario Bureau of Mines Bulletin No. 5, Toronto, 1903.

$30,000 or more, for those having a possible output of 200 tons per day; these estimates are based on European figures and do not usually include the cost of buildings and many minor sundries.

In an estimate made in 1902 and furnished Mr. F. H. Mason,[1] U. S. Consul General at Berlin, by the company controlling the Stauber process of drying and briquetting peat, the following quotations are made for a plant with a capacity for putting out 50 tons of briquettes per day:

Buildings	$14,280
Machinery	17,850
Steam engine and fixtures	3,570
Tram-ways and cars, etc	3,570
Total	$39,270

When it is remembered that a plant for producing cold compressed or condensed peat, air dried, with a capacity of 40 tons of finished fuel per day, may be had for about 1-7 of this sum, it is not remarkable that the statement is frequently made, that in Europe the cold compressed peat is much more largely made and used than the briquetted type, but it is also to be borne in mind that large peat briquette factories have been in operation in Germany and other parts of Europe for some years, and have been apparently successful, especially in Russia, and it is probable, that where the conditions are favorable in this country, peat briquettes can be made on a large scale and sold with profit, especially when the plant and equipment are properly planned, and economically and scientifically managed. It must be considered, however, that it is likely to be the case that for a long time to come the demand for peat fuel will not be from the large consumers, except in regions remote from the coal fields, but from those who use only small supplies, mainly for domestic purposes, and that this demand is relatively small, hence there is no reason for the development of large plants at the present time.

It may be said regarding this matter, however, that existing plants, wherever they have been built in this country, have had orders for more fuel than they have been able to make, and if they could have filled them would have been able to build up a still larger demand, since customers have expressed themselves as pleased with the qualities of the briquettes as fuel. Whether the same results would not have been obtained with a well-prepared article of condensed peat, made at much less cost, is still an unanswered question.

Machines for the preparation of seared briquettes are of the nature of molding machines of the roller pattern, in which the rolls are heated sufficiently, either to simply liberate a part of the tar of the peat, or, in some processes which have been patented, to liberate most of the volatile matter, and form a coke, or carbonized briquette. The former has passed beyond the experimental stage, as noted in another place, but so far as has been found out at present writing, the latter process is not yet fully perfected.

There are so many manufacturers of machinery for briquetting various

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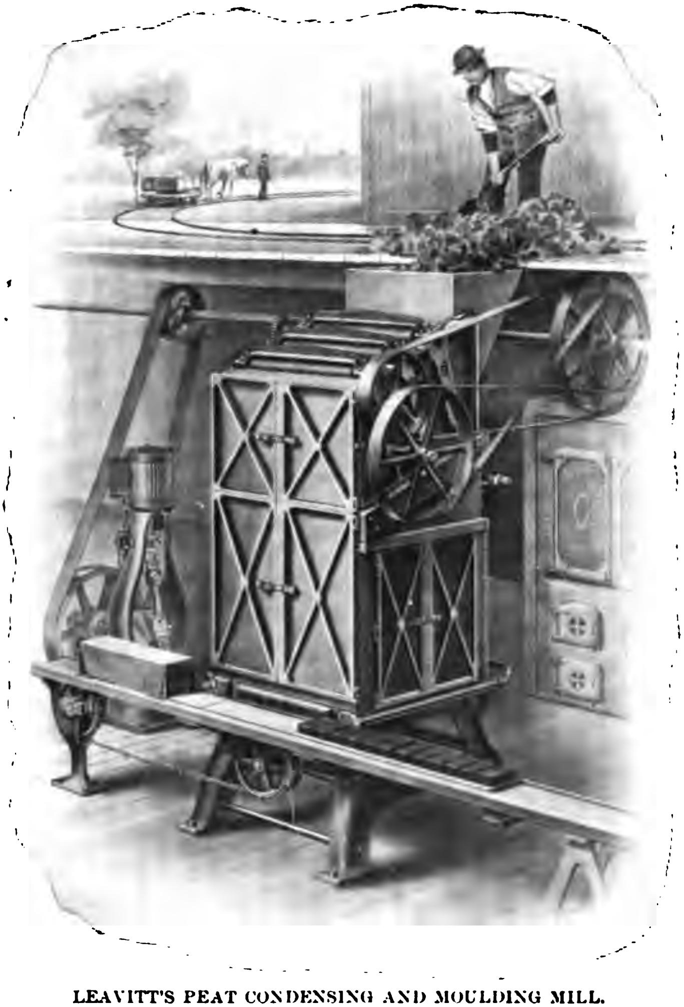
[1] Mason, F. H., Special Consular Reports, Vol. XXVI, p. 81, Washington, 1903.



LEAVITT'S PEAT CONDENSING AND MOULDING MILL.
PERFECTED.

fuels and other substances, that no attempt is made her to give a list of them, but it may be said that in a publication[1] of the State Department, at Washington, already mentioned, the names of some of the principal European makers of such machinery are given, together with much other valuable information relating to the manufacture and use of briquettes. J. C. Bordollo & Co., whose address is given below, are the American representatives of some of the prominent European manufacturers and can be consulted where immediate information is required, and are prepared to furnish various articles on peat.

Methods of Coking Peat.

Processes for coking peat have already been quite fully discussed, and the cost of plants for this purpose mentioned. But little special machinery for the actual operation of coking has been required, since this is performed in some kind of kiln, or closed retort, similar to that used for making coke or charcoal, although several types of closed kilns of the retort type have been patented, but for rendering the preliminary operations of digging, grinding and molding, drying and conveying to the kilns, automatic, and as cheap as possible, several patented machines have been developed, as well as those for recovering by-products from waste. Of somewhat different nature from others, is the patented coking process covered by U. S. patent No. 732,097 and controlled by F. C. Rockwell, Hartford, Conn. In this process, the standard kilns are 32 feet long, 3 feet 9 inches wide, and 5 feet high, each costing about $1,000, and having an estimated capacity of 6 or 8 tons of coke in 24 hours, the product costing, according to published figures, not to exceed $3.00 per ton at the mill. Not less than four of these kilns should be used for a single plant, and a larger number can be cared for by one man. In using these kilns, the peat has to be molded and dried before coking, as it does in other processes, and no special devices are mentioned for these purposes, in the description of the process.

Machinery for the Manufacture of Peat Litter.

A considerable development of special machines for the manufacture of peat litter and peat mull, or peat dust, has been made by the European manufacturers of peat working machinery. Those manufactured by A. Heinen, Varel, Germany, are of excellent patterns and construction, ranging from a small hand machine, which has a daily output of about 4 tons of litter, to one having a capacity of about 20 tons and requiring an engine of 6 or 8 horsepower to run it. These machines consist of toothed rollers, of large diameter, the teeth being long and more or less curved, to shred up the coarse material in the peat. The shredded mass in the hand power machine passes directly from the shredder to a horizontal, revolving, cylindrical sieve, where the finer parts are screened out, after which the coarse stuff may be baled, either by hand, or power balers, made by the same makers.

Peat mull is the name given to finely ground peat, prepared and used in Europe for various purposes, especially as an absorbent and disinfectant. This substance is prepared in upright grinders run by power, or even by hand. The material falls upon a sieve which sorts it, the finer parts falling into a receptacle and the coarser retained upon the sieve. The capacity of these machines is from 5 to 15 tons per day of coarse and about one-half as much of fine mull per day.

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[1] Briquettes as Fuel in Foreign Countries, Consular Reports, Volume XXVI, Washington, D. C. 1903.

In a properly arranged plant for the manufacture of these products, the dried peat would be dumped from the barrows or cars which bring it from the drying ground, into the shredding machine, from which both fine and coarse material could be elevated to a properly placed screen hopper, so that the finer parts of it could be sent by chute to a mulling mill, while the coarse material passes on to a revolving cylindrical sieve which still further cleanses and sorts it, the finer parts going to the muller and the coarse to a baler placed below. The fine material could pass from the mulling machine directly to the packing machine. Such a plant should not be expensive and could be run in connection with an establishment for making peat fuel, to utilize the fibrous top layers of the bog, these being plowed up and dried just as hay is, by exposure to sun and wind. See Plate 31.

Hand machines for making peat litter are also advertised by Martin, of Ofenberg, by Paul Reuss, of Artern, Saxony, and by the Iron Works of Luneberg, and it is probable that Dolberg and other makers also produce some forms of these machines. It is probable that a corn shredder, with somewhat stronger knives than usual would answer very well to shred the less woody forms of peat for small consumers.

Devices for Carrying Peat from Bog to Factory.

Devices for conveying the peat to the factory have been numerous, but mostly simple. In more extensive plants portable tramways of light rails are laid on the surface of the bog on which cars of small size are run, by man, or horse power, or infrequently by electric trolley. The latter could well be used where a lighting plant was used, or where electric power for any other purpose is developed, and would prove, in the end, economical and more efficient than other forms of motive power in use. In small plants, the peat is wheeled by hand in barrows, or in small carts, drawn by a single horse, where the surface of the bog is not too soft. Both of these are expensive methods, even for a small plant, for the loads which can be drawn are light and progress is slow. In a few cases, it has been reported that the peat has been dredged from in and around bodies of water and placed on flat boats, which are poled or rowed to the factory, but much time would be consumed in this way in most cases, and a more satisfactory way, if scows were used, would be to tow them, when loaded, by a small steam or gasoline motor tug boat.

In one case it was reported that the peat, in slurry form, was piped a considerable distance to the factory. A recently recommended method[1] is that the peat, in liquid form, be removed from the bog to a large settling or receiving basin, through trenches cut in the bog and given sufficient artificial fall to insure the flowage of the peat. This plan is feasible, provided that the water is present in sufficient quantities to mix with the peat, but in many Michigan bogs it would have to be pumped into the ditches, and mixed with the peat, to make the latter substance fluid enough to flow.

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[1] Bordollo, J., Peat Fuel Production. The Engineer, May 15, 1906, p. 335.

It is apparent from statements made in this and preceding sections of this report, that the study of this interesting natural resource has gone much farther in the countries of Northern Europe than it has in America, and especially has the investigation of the commercial possibilities of peat, and the development of compact, handy, and durable machines for the manufacture of the various products to be derived from it, gone far beyond the experimental stages. It is, therefore, not necessary for manufacturers or inventors to begin at the beginning to develop machines or processes of utilizing peat, since, in the great majority of cases, they would probably only repeat the errors of those who have gone over the same ground abroad. At the present time it would be a great saving of time and money to study the latest and most improved products of the most progressive foreign manufacturers, especially those of Germany, and the recently prepared reports of investigations into the possibilities of peat utilization, issued in the technical journals or in form of manuals and popular guides, and in the proceedings of the European peat culture societies, before deciding upon inventing new machinery, or new processes of preparing peat for fuel, or for other purposes, for in many cases, most in fact, it would be found that the projected plan had already been tried, and if a practicable one, had long ago been embodied in a machine, and perhaps abandoned for a better one. As was recently stated, there is no such thing as a really secret process for making peat fuel, since all the secrets of the substance were long ago discovered and made known, and the sooner investors and inventors realize this, the sooner there will be in the United States a well developed industry based upon the peat deposits which are so widespread and extensive within the nation's boundaries.

Peat Factories and Peat Prospects in Michigan, Established or Projected.

There are several plants for the manufacture of peat fuel established in the Southern Peninsula, some of which have, within the year (1906), produced some peat, but none, so far as known, are yet running on full time, or are producing peat fuel in quantities. The plants of the American Peat and Fuel Company, near Capac, was, as noted elsewhere, leased after a trial of 30 days, and later sold, to a company which took over the property to manufacture paper and other products from the peat, which seemed especially adapted for this purpose, being rich in fibrous sedge and grass remains below the top layer.—The Pilgrim Paper Co. of N. Y. and Capac.

The Peat and Fuel Company was to make briquetted peat, using the Cooley dryer, and a specially constructed press. The briquettes made were of sufficient density, and of a light brown color, but were easily split and quite brittle, so that they did not stand handling well. This seemed, in part at least, due to the coarseness and lack of cohesiveness of the peat, but as it was compressed into briquettes without any preliminary treatment except drying, it is possible that this might have been remedied. The Capac bog is described in Part I of this report.

The National Peat Fuel Co., of Chelsea, has a good deposit of peat on the border of the town, and near the Michigan Central R. R. The building is a substantial but small brick structure, and small openings have been made in the surface of the bog and some peat has been taken out by hand, but no great amount of fuel has been made. The plant is equipped with a press for making briquettes developed by the owners. The plant was, at last accounts, closed down indefinitely.

The Bancroft Peat Fuel and Cement Co., Ltd., Bancroft. This plant was equipped for making briquettes after the system in use at Whitewater, Wisconsin, to manufacture seared briquettes. The peat was dug from the bog with a steam digger and it was reported that the surface material was used for litter. The plant was operated a part of the summer of 1905, but no report was obtained of the actual output of fuel. The bog on which it is located is reported as having an area of 700 acres and has been partly cleared, ditched and drained, the draining, as usual, causing some settling of the surface.

The Michigan Peat Co., Eaton Rapids, are reported as having a plant equipped for making briquettes, using a patented English system in which the peat is electrically treated before briquetting, to hasten the process of drying.

The following companies have established factories for making condensed, or cold compressed air-dry peat fuel:

The Michigan Peat and Marl Co., Grand Rapids, equipped with a Heinen press.

The Wolverine Peat Co., Vicksburg, equipped with a Dolberg press.

Carl G. Kleinstück, Kalamazoo, is reported by local newspapers to have manufactured some pressed peat fuel for local consumption, but no details of his equipment have been obtained.

A company called the Van Buren Peat Co., Gobleville, has been organized, and is planning development of bogs in that vicinity.

A plant is reported as in operation in Mecosta county near Big Rapids, but no information relative to its equipment has been obtained.

Beds of peat of considerable extent, which have at some time been the basis of prospective plants, or for the organization of companies for their utilization, are reported at or near the following places:

Kalamazoo, large extent.

Three Rivers, large bogs, 2 miles distant.

Minden Tp., Sanilac county, near Croswell. 6,000 acres.

Quanicassee.

Summerfield township, Clare county, 100 acres in one body. 6 to 12 feet deep. (Harrison the nearest town.)

Hanover, 40 acres.

Decatur, 100 acres, 6 to 8 feet deep.

Bass River, 100 acres, 6 feet deep.

Morenci, 200 acres or more.

The latter bogs are all too small for large establishments but would supply fuel for local consumption, for many years, provided the peat is of average density and fuel value, since each acre would furnish from 150 to 200 tons of dry fuel for each foot in depth, after the surface material has been passed through.

Conclusion.

It is probable, as has been intimated elsewhere, that the best way in which quick and sure returns may be realized from peat bogs, is by developing them with the idea of supplying small local markets, rather than attempting to compete with the better known and more widely used fuels on a large scale. Where the former course is taken, a relatively small bog, a small investment, and a local market, with a limited requirement in quantity, should make a combination which should be satisfactory to the owner and investor, who could then afford to give his customers a fair price, which should run considerably below that paid for ordinary fuels and still give good profit. When the numerous bogs of Michigan are thus utilized, as many of them will be, before many years, the peat fuel industry will be placed upon a proper footing.

Acknowledgments.

In the preparation of this paper, the writer has made free use of the relevant matter contained in numerous short articles and papers by other writers, to which no special reference has been made, since many of them were anonymous. The daily and weekly papers, magazines, both popular and scientific, technical periodicals, and scientific reports and manuals have all furnished much valuable material and in this place the writer's obligations to these sources are acknowledged. The catalogs of European manufacturers of machinery and their agents have given a great deal of important matter. The late T. H. Leavitt, of Boston, a pioneer in the development of peat fuel machinery in this country, and J. Bordollo of Kingsbridge, N. Y., have kindly loaned cuts which have been used in illustrating this paper.

Especial thanks are due to Professor J. R. Allen, of the University of Michigan, for analyses furnished as well as for much information based on a wide experience with the practical side of peat utilization, and to Mr. Alfred C. Lane, State Geologist, for many suggestions as to the treatment of the subject, for innumerable references to literature and citations of authors, as well as for information relating to the progress of the development of factories for the utilization of peat in the state and for much other matter of interest.

Thanks are also due to the owners of peat bogs over which the writer has made his way and for the interest and co-operation of these, whenever they have been asked for information.

INDEX.

INDEX.

(See also list of Latin and common specific names on pages 281 to 286.)

A.

Abies balsamea, see Balsam. Page
Acer rubrum 147, 150, 156, 283
  saccharum, see Hard Maple.
  spicatum, see Mountain Maple.
Acetate of Lime 301, 303
Acidity, peat 320
Acids, organic, muck land 291
Acknowledgments 361
Acorus Calamus, see Sweet Flag.
Acre of peat, tons of fuel 277, 318
Adams, C. C. cited 173, 270
Adder's Tongue Fern 141
Admont, Austria, peat tested for paper 308
Aerating system, Tamarack 130
Aerenchyma 204
Agricultural crops, peat litter 298
  possibilities, peat bogs 279, 289
Agrostis alba, see Red Top.
  hyemalis, see Hair Grass.
Air, peat formation 171
Akron, township marsh land 109
Alder swamps, peat deposits of 121, 123
Alders 168, 195, 210, 211, 215–217, 220, 236, 242, 243
Algæ 129, 209, 210, 231, 322, 323
  microscopic 263
Algal deposit 203–210, 247, 263, 270
Algal Lake 203, 204
Alisma plantago-aquatica, water plant 129
Allen, J. R., analyses 327, 329
  acknowledgments 361
  W. H., peat analyses 331
Alma, Ilicoides mucronata at 163
  moraine dam 117
  Pine river, dam 118
  Vaccinium corymbosum at 163
    Pennsylvanicum at 162
Alnus incana, see Alder and Common Alder.
Alpine Cotton-grass 201, 203, 264, 282
Amasa, bogs near 231
Amelanchier 263
  Canadensis, see June Berry.
America, peat, early used in 313
American Aspen 281
American Mountain Ash 266, 286
American Wood Strawberry 266, 286
Ames slane, Plate XXIX and 101
Ammonia in peat 293

Page
Ammonium sulphate, nitrates formed with peat.......... 310
  peat coke by-product..........301, 303
Analyses, Michigan Celery soil.......... 294
  Michigan peat..........327 to 332, 338
  peat coke.......... 305
Andromeda..........148, 149, 194, 199 to 269, 281
  growth of, Fig. 13..........101, 235
  Polifolia..........146, 148, 164, 281
Anemone Canadensis, see Canada Anemone.
Ann Arbor, Andromeda Polifolia at.......... 164
  Betula pumila at.......... 164
  Cassandra at.......... 163
  Dasiphora fruticosa at.......... 162
  Gaylussacia resinosa at.......... 162
  glacial drainage valley at.......... 119
  Ilex verticillata at.......... 163
  Ilicoides mucronata at.......... 163
  morainal dam at.......... 117
  Spiræa tomentosa at.......... 164
  Tamarack at.......... 164
  till plain near.......... 119
  Vaccinium Canadense at.......... 162
    Pennsylvanicum at.......... 162
Ann Arbor R. R., bogs..........109, 154
Anthracite and coked peat.......... 335
Antoine, Lake, pine "island," Plate XXIII.......... 101
Aquatic plant societies.......... 265
  plants..........220, 224, 226, 274
Aralia hispida..........162, 284
  See Bristly Sarsaparilla.
  nudicaulis.......... 150
Arbor Vitæ..........109, 118, 122, 135, 189–193, 196, 202, 203, 206, 266, 281
Arcada township, beaver dam.......... 168
Arctostaphyllos Uva-Ursi, see Bearberry.
Area, peat deposits.......... 318
Arethusa.......... 203
Arizona, sunshine.......... 113
Aronia arbutifolia..........163, 282
  See Choke-berry.
  nigra..........147–149, 157, 165–282
Arrow head..........129, 241, 248
Arrow-arum..........139, 141
Arrow-grass..........210, 281
Arundo Phragmites, peat formation.......... 126
Asclepias incarnata..........144, 283
  See Swamp Milkweed.
  Syriaca.......... 144
Ash, peat..........319, 320, 326, 329, 330-335, 341
Ash to commercial value, relation of.......... 325
Aspen..........156, 189, 197, 211, 214, 266, 281
Asphaltum, peat coke.......... 303
Aster.......... 219
Aster junceus.......... 140
  puniceus.......... 144
Athabasca, beaver dams.......... 168
Atkinson, G. F., peat formation..........128, 173
  sphagnum atolls.......... 151
Austria, peat paper made in.......... 308

B.

Bacteria, agents of decomposition.......... 106
Badwater Lake, lake near, Plate XXIV, XXV.......... 224
Balsam..........189–193, 195, 196, 221, 241, 249, 261, 262, 264, 266
Balsam Fir.......... 284
Balsam Poplar..........193, 224, 284

Page
Balsam, spruce bog at ... 101, 232
Bancroft Peat Fuel and Cement Company: ... 360
Bancroft, seared briquettes made at ... 340
Barren Strawberry ... 227, 284
Bass Lake, tarn ... 116, 132, 151, 159, 163
Bass River, peat bogs ... 360
Basswood ... 188, 190, 191, 196, 204, 261, 281
Batrachium, water plant ... 128
Bay county, prairie ... 124
Beach, A., reference ... 173
Beaked Hazelnut ... 236, 282
Beal, W. J., reference ... 173
Bear Lake, buried peat near ... 243
Bearberry ... 236, 245, 251, 281
Beaver dam, Negaunee, Plate XIV and XV ... 101
Beaver dams ... 119, 167–169, 263
Bebb's Willow ... 144, 211, 285
Bedding, peat litter ... 295, 298
Bedstraw ... 140
Beech ... 188, 190, 191, 196, 203, 281
Benerberg, peat coke made at ... 302
Bentley's camp, Black Spruce-Heath, Plate XXVIII A and B ... 101, 185
Bessemer, mature peat bog north of, Fig. 14 ... 101, 185, 238
Betula lenta, see Black Birch.
  lutea ... 150, 156, 281
    See Yellow Birch.
  papyrifera, see White Birch.
  pumila ... 142, 157, 162, 281
    See Dwarf Birch.
Bibliography, peat ... 173, 179
Bidens Beckii ... 128
  cernua, see Smaller Bur-Marigold.
Big Rapids, peat plant ... 360
Bill-board paper ... 308
Birch ... 166, 204, 241, 266
Black Alder ... 142
Black Ash ... 156, 189, 192, 193, 196, 281
Black Bindweed ... 267, 285
Black Birch ... 190, 191, 261, 281
Black sand, Marquette ... 254
Black Spruce ... 142, 146, 148, 165, 189, 266, 284
Black spruce at Balsam, Plate XXVI ... 101
Black Spruce-Heath Association, Bentley's camp, Plate XXVIII B ... 101
Black Spruce-Tamarack association ... 242
Black Willow ... 156
Bladder Sedge ... 265, 286
Bladderworts ... 128, 129, 137
Blankets made from peat ... 308
Blocks, peat paper ... 308
Blue Flag ... 144, 229, 233, 238, 241, 242, 247, 252, 255, 256, 264
Blue Grass ... 285
Blue Joint Grass ... 144, 168, 197, 206, 211, 216–218, 220, 229, 231, 233, 238, 242, 246, 263, 264
Blue Vervain ... 144, 219, 285
Blueberry ... 148, 165, 194, 232, 248, 266, 274
Blueberries ... 123
Bœhmeria ... 143
    cylindrica ... 140, 142, 144
Bog Club-moss ... 255, 282
Bog, defined ... 109, 110
Bog iron ... 254, 324
Bog, Lake Antoine ... 220, 221
Bog, mature ... 212, 228, 231, 238, 258
  mature border near Nathan, Plate XXII ... 101
  near Iron river ... 237
  near Runkle Lake ... 231

Page
Bog plants, Faunus Station 215
  Manistique 259
Bog near Clara Lake 233
Bog, spring, near Camp Lake 230
Bog, spruce at Balsam 232
Bog, T. 50 N., R. 30 W., flora 263
Bog, Valley, near Granite Bluff 223
Bog, Wintergreen 202, 210, 212, 213, 285
"Bog xerophytes" 164
Boggy lake, T. 40 N., R. 30 W 226
Boghead cannel coal 306
Bogs between Newberry and Grand Marais 246
Bogs, cleared 214
Bogs, conifer type 257
Bogs, Crystal Falls 228
Bogs, ecological study 183
Bogs, Hermansville 212
Bogs, Keweenaw Peninsula 240
Bogs, mature, near Mary Lake 236
Bogs near Amasa 231
Bogs near Badwater lake 224
Bogs near Faunus 214
Bogs near Marquette 245
Bogs near Twin Falls 226
Bogs near Vulcan 217
Bogs, peat, Huron Mountains 260
Bogs south of Crystal Falls 233
Bogs, Trout Lake 249, 250
Bogs, types of 262
Boilers, peat fuel for 333
Bordollo, J., acknowledgments 173, 352, 357, 361
Bottle Sedge 211, 229, 233, 236, 271, 272, 284
Bottom, peat relation to 323
Boyce Lake, heath swamp, peat deposits 124
  Ledum Grœnlandicum 164
  Sphagnum 163
  succession of plants near 159
Bracken Fern 189
Bradford, G. M., peat bog studies 183
Brake, see Common Brake.
Brasenia purpurea, see Water Shield.
Briquetting peat 312, 352, 354
Bristle-stalked Sedge 195, 206, 207, 210, 212, 284
Bristly Crowfoot 282
Bristly Sarsaparilla 214, 266, 284
Bristly Sedge 196, 230, 238, 284
British Thermal Units of heat, etc. (See Analyses) 334
Broad-Leaved Arrow-Head 141, 216, 238, 243, 281
Broad-leaved type of forest 189, 191, 266, 274
Brosowsky machine, cut peat 101, 344
Brown, F. B. H., cited 173
Brown, R., peat formation 125, 173
Buck-bean 141, 143, 199, 201, 203, 206, 207, 212, 216-218, 222, 225, 226, 228, 230, 234, 235, 238, 242, 251, 281
Buckthorn 195, 202, 212, 216, 231, 281
Bugle-weed 140, 264, 265, 285
Building ("Heloxyle") peat paper 308, 309
Bulb-bearing water Hemlock 216, 218, 219, 225, 243, 251, 285
Bulldog Lake, algal peat 263
Bulrush 201
  zone 260
Bunch Grasses 255
Bunch-berry 195, 206, 213, 223, 227, 230, 237, 250, 251, 282
Bur Oak 156
Bur reed 129, 229, 247, 248, 282

Page
Buried peat, Lake Superior shore 243
  near Marquette 252–254
Burning of bogs 219
Burns, G. P., peat in Dead Lake 122
  reference 173
Bush Honeysuckle 197, 283
By-products, peat 299–305

C.

Cadillac, tamarack peat 122
Calamagrostis Canadensis 144, 145, 168, 282
  See Blue-Joint Grass.
Calcareous bottom, Europe, peat formation on 125
Calcareous soil, water 161
Calcium carbide 303
Caledonia Springs, peat deodorizer 297
California, peat bogs 110
Callitriche bifida, see Northern Water-Starwort.
  palustris 284
Calopogon 203, 206, 210, 282
Caloric cookers, peat as packing for 309
Calories in peat 326, 334
Camp Lake 229
  spring bog near 230
Campanula aparinoides, see Marsh Bell-flower.
Canada Anemone 219, 281
Canada, beaver dams 168
  Blueberry 148, 200, 206, 214, 223, 227, 232–234, 237, 239, 241, 245, 248, 250, 262, 264, 266, 281
  Golden-rod 144
  peat bogs 111
  peat deodorizer 297
  peat fuel 313
  St. John's-wort 219, 264, 265, 284
Cannel coal, origin of 209, 210
Capac Peat Company, peat tests 338
Capac, peat deposit, beaver dam 119, 169
  peat paper 307, 309
  tree remains 170
Capnoides sempervirens, see Pale Corydalis.
Cardboard 307, 308
Carduus muticus, see Water Thistle.
Carex aquatilis 139, 284
  See Water Sedge.
  canescens 150
  chordorhiza, see Creeping Sedge.
  comosa, see Bristly Sedge.
  filiformis 136, 137, 139–141, 145, 146, 148, 284
    See Slender Sedge.
  flava, see Yellow Sedge.
  folliculata, see Bladder Sedge.
  hystricina, see Porcupine Sedge.
  leptalea 142, 284
    See Bristle-stalked Sedge.
  limosa 141, 145, 146
  Magellanica, see Magellan's Sedge.
  oligosperma 149, 284
  pauciflora 147, 149
  Pennsylvanica, see Pennsylvania Sedge.
  riparia 150, 284
    See River-bank Sedge.
  Sartwellii 139, 141, 284
  sp., water plant 130, 133, 134, 136, 137, 139, 143, 147, 150, 166, 194
  sterilis, see Little Prickly Sedge.
  sterilis cephalantha 142, 143

Page
Carex stricta 135, 143, 144, 284
  See Tussock Sedge.
 tenella 142, 284
  See Soft-leaved Sedge.
 teretiuscula 141, 284
 trisperma 142, 150, 284
  See Three-leaved Sedge.
 utriculata 139, 284
  See Bottle Sedge.
 vulpinoidea, see Fox Sedge.
Carpenter, R. C., reference 292
Carpets, made from peat 308
Carrying peat, bog to factory 358
Carter, W. E. H., Canada peat bogs 111
  reference 173
Cass river, moraine dam 117
Cassandra 145, 146, 148, 149, 163–166, 194–197, 199–202, 205–208, 214, 216–218, 220, 221, 223–239, 241–243, 245–252, 256–258, 262–266, 269, 282
Cassandra, lake growth, Fig. 13 101
Cassandra zone 146, 147, 150, 212
Cassandra-Sphagnum zone 148, 149
Castalia odorata, see Sweet-scented Water Lily.
Castalia reniformis 139
 sp., see White Pond Lily.
 tuberosa, seed plant succession 133
Cat-tail 129, 139, 141, 145, 194, 196, 205–207, 210–212, 216–218, 220, 227, 228, 234, 241, 243, 246, 247, 250, 271
Cedar 166, 169, 189, 192–194, 214, 215, 228, 230, 234, 246, 273, 282
  See Arbor Vitae.
Cedar Lake, marl beds, peat 131, 132
  tarn 116
Cedar swamps 121, 126, 132, 163
Cedar-Spruce zone 196
Cedar-Spruce-Tamarack association 191, 192, 206–209, 215
Cement burning rotaries, peat coke 341
Cerastium vulgatum, see Mouse-ear Chickweed.
Ceratophyllum 129
Chamædaphne calyculata 145, 147, 282
  See Cassandra.
Chamænerion angustifolium, see Great Willow Herb and Fire-weed.
Chamberlin, T. C., reference 174
Chara 126, 129, 131, 197, 321–323
Chara zone 269
Charcoal iron, peat coke 240, 278, 341
Charcoal, Sphagnum peat 157
Charlevoix, Pine Lake 117
Cheadley, beaver dams 168
Chelsea, bog swamp, Polytrichum 125
Chelsea, National Peat Fuel Company 331, 359
  peat deposit 162
Chelsea, slope bogs near 120
Chemical composition, peat 319, 320
  vegetable matter 105
Chenopodium album, see Pigweed.
Chiogenes hispidula, see Creeping Snowberry.
Choke Cherry 266, 285
Chokeberry 147, 149, 157, 195, 234, 236, 247, 248, 250, 255, 257, 258, 266, 274, 282
Cicuta bulbifera, see Bulb-bearing Water Hemlock.
 maculata, see Spotted Cowbane.
Cinnamon Fern 143, 206, 207, 241, 242, 248, 282
Cladonia 124, 283
  See Reindeer Lichen.
Clara Lake, flora and sedge bog near 233
Clare county, peat bogs 360
Clark, A. N., peat analyses 330
 H. L., reference 174

Page
Classification Michigan peat deposits........114, 120, 121
Clay below peat........323
Clay till ridges........188
Clearing bogs........219
Climatic conditions of, effects of on plants........130, 261
Climax stage, bog........257, 258
Climbing bog........120, 264
Clintonia........206, 207, 227, 230, 237, 250, 267, 282
  borealis, see Clintonia.
Closed Gentian........264
Coats made from peat........308
Coke, peat........299–305, 341
Coking peat........335, 357
Coldness of muck........290
Cole, Leon J., St. Clair delta........120
  reference........174
Comarum palustre........141, 143, 146
Commercial value of peat........95, 317, 325
Common Alder........194, 212, 213, 218, 219, 222, 224, 227, 228, 231, 234, 238, 245, 248, 251, 252, 255, 256, 263, 266, 281
  Bladderwort........197
  Blueberries........227
  Brake........150, 197, 214, 227, 234, 237, 245, 250, 257, 258, 267, 281
  Floating Pondweed........220, 226, 283
  Horsetail........210, 230, 283
  Milkweed........144
  Polypody........266, 286
  Smartweed........219, 284
  Sundew........212
Comparative value peat........329
Composition, Michigan peat........327
Composting, peat........293–295
Comptonia perigrina, see Sweet-fern.
Condensation of moisture, peat formation........268
Condensed peat, machines for making........346
Congleton, peat deodorizer........297
Conifer bog near Mansfield, Plate XIX........101
Conifer type of bogs........257
  zone........210, 212, 222, 227, 230, 231, 242
Conifer-Heath plant societies........194, 265, 266
Conifer-Shrub association........243, 245
Coniferous Swamp Forest........191, 192
Consolidation of peat deposit........138
Contamination producing high ash content........320
Cooley dryer........354
Coptis trifolia........142, 143, 150, 282
  See Goldthread.
Cornus Amonum, see Silky Cornel.
  Canadensis, see Bunch-berry.
  candidissima........142
  stolonifera........142, 144, 283
  See Red Osier.
Corpse plant, see Indian Pipe.
Corrosion of grates........335
Corylus Americana........157
  rostrata, see Beaked Hazel-nut.
Cost of preparation, peat fuel........342, 352
  peat coke........303
Cotton-grass........230, 250
Coulter, J. M., reference........174
  S. M., flora succession........159
  S. M., reference........174
Courtney, J. N., analyses........331
Cow Wheat........237, 282
Cowles, H. C., cited........109, 128, 160, 174

Page

Cranberries 146, 149, 196, 200, 210, 245, 248
See also Large Cranberry and Small Cranberry.
Creeping Sedge 199, 216, 225, 251, 271, 272, 284
Snowberry 200, 202, 206, 210, 212, 222, 223, 230, 232, 234, 239, 241, 245, 249, 250, 266, 284
Spikerush 133, 218, 224, 234, 238, 242, 256, 265, 284
Crevice plant societies 265
Croswell, peat bogs 360
Crowfoot family, water plant 128
Crozier, A. A., reference 292
Cruciferæ 128
Crystal Falls, bogs and lakes near 185, 228, 231
lakes and bogs south of 233
Crystalline rock outcrops, peat examination in region of 188
Cut peat, machinery for making 344
Cut-leaved Water Hoarhound 144, 219, 283
Cycle of plant growth 166
Cypripedium acaule 147, 149, 150, 283
See Stemless Ladies' Slipper.
Cypripedium reginæ, see Showy Ladies' Slipper.

D.

Dal, Adolf, peat and electricity 306, 327
Dams, deposits formed behind 167
Dana, J. D., peat bogs 110, 174
S. L., reference 174
Daniels, F. P., reference 174
Danthonia spicata, see Wild Oat-grass.
Dark-green Bulrush 211, 282
Darwin, Chas., peat 110, 174
Dasiphora fruticosa 144, 162, 282
Davis, C. A., peat in Michigan 93, et seq
reference 174
Dead Lake 122, 145, 159
Decatur, peat bogs near 360
Decodon verticillatus 130, 132, 139, 146, 151, 152, 283
See Swamp Loose strife.
Decomposition, agents of in vegetable matter 106, 183
Deep bogs, peat with water or marl below 319
Deer Park Life Saving Station, Lakes near 248
Delta St. Clair river 120
Denmark, peat fuel in 105
Deodorizer and disinfectant, peat as 297
Deposits formed behind dams 167
Depressions filled from sides and top by peat 135
formation of peat in 130
Depth, peat deposits 183, 318
Desor, E., beaver dams 167
driftwood dams in Manistique river 118
on peat formation 126
reference 174
Destructive distillation of peat 299
Detroit and St. Clair rivers, marsh near 109
beaver dams near 167
river, sedge marsh 124
Dexter, sedge marsh, peat deposit near 124
Diatoms in peat deposits 323
Dickinson county, plant societies of 184
Dickson press, peat briquettes 355
Diervilla Diervilla, see Bush Honeysuckle.
Digging machines, peat 346
Disinfectant, peat, farm use 296, 297
Dispersal of seeds 165
Dissolved mineral matter 322
Distillation, destructive of peat 299
Distribution, peat bogs and plants 181, 188

Page
Dobson press, for making peat briquettes.......... 355
Dog Violet.......... 266, 286
Dogwood.......... 142
Dolberg, R., peat machines.......... 346, 348
Drainage, possibilities of in peat bogs.......... 320
Drosera rotundifolia, see Round-leaved Sundew.
Drumlins, peat examination in region of.......... 188, 193, 214
Drying peat, machinery.......... 352, 353
Dryopteris Thelypteris.......... 140–142, 143, 144, 147, 157, 158, 282
    See Marsh Shield Fern.
Dulichium.......... 146, 218, 225, 234, 238, 242, 243, 245, 249, 252, 255, 256, 257, 265, 271, 282
Dune regions.......... 116
Dwarf Alder.......... 195
    Birch.......... 142, 157, 159, 194–216, 220, 236, 257, 281
    Blueberry.......... 148, 223
    Raspberry.......... 142, 195, 206, 210, 212, 284
    St. John's-wort.......... 265
    Sand Cherry.......... 248, 282
Dye, peat.......... 310

E.

East Friesland, moors of.......... 115
Eaton Rapids, Michigan Peat Company.......... 360
Eckerman, Great Swamp west of.......... 246
Ecological factors.......... 160
    study, bogs and marshes.......... 183
Ecology of peat formation.......... 105
Economic considerations, peat.......... 277
Edaphic factors.......... 170
Eight Mile Creek, peat bog on.......... 238
Eiseln, J. C., references.......... 115, 175
Electrical action, drying peat.......... 337
Electricity, peat, source of.......... 280, 310, 327
Eleocharis.......... 130
    acicularis, see Spike-rush.
    palustris.......... 133, 284
    See Creeping Spike-rush.
Elevation, Huron Mountains.......... 260
Ells, R. W., reference.......... 175
Elm.......... 142, 147, 190, 191, 204
Elm and Black Ash swamps.......... 121
"Embarras".......... 118
Endogens, water plants.......... 129
England, peat bogs of.......... 111
    peat paper made in.......... 308
English cannel coal, gas yield of.......... 306
    Fen country, peat formation in.......... 125
Epigæa repens, see Trailing Arbutus.
Epilobium coloratum, see Purple-leaved Willow-herb.
Equisetum.......... 143, 323
    arvense, see Common Horsetail.
    fluviatile.......... 142, 285
    See Swamp Horsetail.
Erigeron Philadelphicum, see Philadelphia Fleabane.
Eriocaulon septangulare, see Pipe-wort.
Eriophorum.......... 143, 194
    alpinum, see Alpine Cotton-grass.
    gracile.......... 146, 282
    polystachyon.......... 142, 146
    See Tall Cotton-grass.
    vaginatum.......... 149
    Virginicum.......... 149, 282
    See Virginia Cotton-grass.
Eskers, peat examination in region of.......... 188
Estimated cost of peat plant.......... 352

Page
Eupatorium perfoliatum 140
  purpureum 140, 144, 284
    See Joe Pye-Weed.
Europe, peat bogs 111
Exposed rock plant societies 265
Extent, peat beds in Michigan 183, 326

F.

Fabrics woven from peat 308
Factories, peat, Michigan 359
Fagus Americana, see Beech.
Fall, Delos, peat analyses by 331
False Lily-of-the-Valley 143
  Nettle, Plate XVI 140, 206
Farmer, map of swamp distribution, Plate XVI 101
Faunus Station, bog plants near 215, 221
Feather-board paper 308
Fen Orchis 143
Fenton Township, Long Lake 137
Fern association, sedge mat 158
Fern "islands" 159
Ferrous sulphate in peat 291
Fertilizer, peat 293
Fetid Currant 266, 285
Few-flowered Sedge 222, 228, 232, 235, 239, 241, 242
Few-seeded Sedge 214, 228, 236, 237, 239, 241, 249, 257, 264, 271, 272, 284
Filled Lake near Nathan 201
Filling, southern and northern lakes compared 269
  types of 270
Fir Balsam 281
Fire, not to be used to excess on muck land 292
Fire-proof peat paper 308
Fire-weed 267, 285
First Sister Lake, tamarack swamp at 122
Fisher, moors 115
Flat areas, peat formation on 134
Flat-leaved Bladderwort 201, 236, 281
Floating Bur-reed 265
  Manna-grass 129, 256, 265, 282
  Pondweed 197, 199
Flooding by streams, peat beds 321
Flora, zonal affinities of 184
Florists, peat litter as packing material 309
Flowering fern 140, 143
Fog, effect on peat growth 264, 268
Fontinalis 199, 215
Ford river, bog plants near 215
Forest, types of in Northern Peninsula 191
Forests, north and south hillsides, in Huron Mountains 261, 262
Formations of peat near Manistique 254
Formation of peat bogs 181, 251
Foster City, bogs near 214, 215
Four Mile Lake, Chara, marl the chief deposit 131
  Sedge marsh at 124
Fox sedge 284
Fragaria Americana, see American Wood Strawberry.
Frain's Lakes 151, 152
France, peat fuel used in 311
  peat land in 110, 111
Frankfort, plant distribution 183, 186
Fraxinus Americana 147
  nigra 156, 281
    See Black Ash.
Freyburg, peat coke made at 300

Page

Fringed Loosestrife, see Steironema ciliatum.
 Polygala....230, 283
Fruh, J., moors.... 115
 reference.... 175
Fruits, peat suggested as packing for.... 309
Fuel in one acre of peat....277, 318
Fuel, peat as.... 311
Fuel value of peat.... 332
Fungi, agents of decomposition.... 106

G.

Gale, see Sweet Gale.
Galium sp....140, 143
Galium trifidum....142, 282, 285
 See Small Goose-grass and Small Bedstraw.
Gas, peat....280, 305–307
Gaultheria procumbens, see Wintergreen.
Gaylussacia resinosa....142, 147, 148, 162, 283
 See Huckleberry.
Geikie, A., formation of peat....125, 175
Genetic development, peat.... 187
Germany, peat pasteboard manufactured in.... 308
 peat briquettes manufactured in.... 339
 peat coke manufactured in....300, 341
 peat deodorizer used in.... 297
 peat deposits of.... 110
 peat drainage practice in.... 320
 peat fuel used in....105, 311
Geum strictum.... 144
Glacial drainage valleys.... 119
Glyceria nervata.... 143
Gobleville, Van Buren Peat Company.... 360
Goldthread....142, 206, 207, 210, 213, 223, 230, 250, 282
Goose grass.... 230
Grand Haven celery soil, analysis of 294
Grand Marais....246, 248
Grand Rapids, Michigan, Peat and Marl Company.... 360
Grand Traverse Bay, barrier lakes.... 117
Grand Trunk R. R., bogs along....101, 124, 154–156, 158, 332
Granite Bluff, valley bog near.... 223
Grass marshes and bogs, peat deposits....121, 124
Grasses....255, 282
Grates for peat fuel.... 333
Gratiot county, plants in....122, 162, 163, 164
Great Britain, peat fuel in.... 311
Great Dismal Swamp, peat formation in....126, 127
Great Water-dock....143, 216, 234, 282
 Willow-herb....214, 285
Greater Bladderwort....211, 220, 241, 251, 281
Ground Juniper.... 142
Gyrostachys cernua, see Ladies' Tresses.

H.

Hair-cap Moss....214, 223, 230, 232, 237, 238, 248, 250, 255, 256, 258, 275, 283
Hair grass....267, 285
Hairy Wood-rush.... 206
Half Moon Lake, Alder swamp, peat deposit at.... 123
 peat formation in....136, 159
 plant associations around.... 122
 sedge mats at.... 152
Half-way House, Stuart's Lake near.... 247
Hand machines, for manufacturing peat litter.... 358
Hanover, peat bogs in.... 360
Hard Maple....188, 190, 191, 196, 261, 283
Hardwood forest type....189, 191, 192, 261

Page

- Harrington, M. W., reference 175
- Hartwright's Persicaria 210, 211, 216, 283
- Haslett Park, bog near 156
  - Grand Trunk R. R., Fig 5 101
  - sink hole, analyses of peat from 332
- Hats made from peat 308
- Hausding's Handbuch der Torfgedwinnung 334
- "Hay marshes" 124
- Hayward Lake, manner of filling 195, 197, 198
- Hazelnut 157
- Heat, in relation to growing crops on muck soils 290
  - as a factor in peat formation 171
- Heath bog, Mary Lake 236
  - plants 162, 194, 226, 252, 257, 266, 274
  - swamps, peat deposits in 121, 123, 162–165
  - zones 162, 247
- Heath-Sphagnum zone 222
- Heating power of peat fuel 334
- "Heaving" of crop plants in muck soils 291
- Hedge Nettle 219, 283
- Heinen, A., machinery for making peat 349, 357
- Heinrich, water content of peat 161
- Helenium antumnale, see Sneeze-weed.
- "Heloxyle," paper for building 308–310
- Hemlock 188–192, 204, 241, 249, 261, 262, 283
- Hemlock-White Spruce-Balsam type of forest 192
- Herb-Sphagnum association 264
- Herbaceous vegetation 194, 212, 214, 216, 228, 230, 239, 241, 249, 257, 264, 267
- Herbs, in relation to peat development 142, 144, 147, 158, 232
- Hermansville, bogs near 101, 212, 214
- Heteranthera dubia, water plant 129
- Hill, E. J., reference 175
  - J. J., cost estimate of peat coking plant 304
- Hills, north and south side, forests on 261, 262
- Hippurus, water plant 128
- History of peat as fuel 311
- Hoary Willow 195, 202, 210, 212, 285
  - See Salix candida.
- Hobart Station, bog near 159, 164
- Hobart, White Cedar growing on peat deposit 122
- Holland, moors in 115
  - peat fuel in 105, 311, 339
  - peat land largely utilized in 110
- Holmes, J. A., reference 175
- Holstein, moors in 115
- Hop Hornbeam 261
- Horned Bladderwort 242, 243, 281
- Hornwort family, water species 128
- Horsepower peat machines 348
- Horsetail 224, 323
- Horton, R. E., reference 175
- Hospitals, use of peat in 298
- Houghton, peat bogs near 240
  - Sphagnum growth near 275
  - county, swamp areas 277
- Hubbard, B., beaver dams 167, 175
- Huckleberry 142, 245, 251, 255, 257, 283
- Hudson's Bay, peat muskeg 111
- Humus acid, muck land 291
- Hunt, R. W., marl or peat sampler 317
- Huron county, plants in 162
  - glacial drainage valleys in 119
  - "prairie" 124
- Huron Mountains, list of plants from 285, 286
  - peat bogs in 260

Page
Huron river, cut off channels in valley of 118
  morainal dam across 117
Huron river, slope bogs in valley of 120
Hydrophytic vegetation 151
Hypericum Canadense, see Canadian St. John's-wort.
Hypnum, fluitans, relation to peat formation 124, 125, 126, 134, 158, 159, 203, 210, 215, 216, 218, 229, 231, 251, 267

I.

Ilex verticillata 142, 147, 149, 163, 165, 285
  See Winterberry.
Ilicoides mucronata 147–149, 163, 165, 283
  See Mountain Holly.
Illinois, sunshine in 113
Imlay City, glacial drainage valley 119
Impatiens biflora 140, 143, 285
Impurities, peaty soils 291
Independence Lake, peat deposits at 136
Indian Pipe 147, 239, 267, 283
Indian Rice, water plant 129
Indiana, sunshine in 113
Ingalls Station, Hayward Lake near 195
Ingham county, lakes, sedge mats on 152
Intermediate Lake, barrier formed lake 117
Intermittent lakes 116
Ireland, mountain bogs, formation of 125
  peat deposits of 110, 111
  peat fuel used extensively in 311
  peat paper made in 308
Iris versicolor 144
  See Larger Blue Flag.
Iron, bog 254, 321, 324
Iron county, plant studies in 184
Iron industry, possible use of peat coke in 278
Iron Mountain, Badwater Lake near 224
  Lake Antoine near 219
  River, bog near 237
  sand, above peat bed at Marquette 254
Ironwood 188, 283
Isabella county, lakes in 117, 122, 123, 152
  Littlefield lake in 117
Island lake 248
  lake near 249
"Islands" of trees in bogs 201, 249
Isle Royale, Sedge zones around lakes on 270
Isoetes sp., see Quillwort.

J.

Jack pine 189, 190, 192, 193, 221, 222, 233, 236, 245, 248, 250, 251, 257, 261, 283
Jackson bog, tests of peat from 338
  county, peat analyses 328
James Bay, peat muskeg 111
  township, marsh land 109
Jebsen process, peat coke 304
Jefferson, M. S. W., reference 175
Joe-Pye Weed 140, 144, 211, 219, 228, 284
Johnson, S. W., reference 175
Jukes-Brown, A. J., formation of peat 125, 175
Juncoides, see Wood-rush.
Juncus effusus, see Soft Rush.
  sp., see Rush.
  tenuis, see Slender Rush.
June Grass 267
June-berry 263, 266, 285

Page

- Juniperus communis.... 142
  - nana, see Low Juniper.
  - Virginiana.... 151

K.

- Kalamazoo Celery Soil, analyses of.... 294
  - glacial drainage valley near.... 119
  - peat fuel made at.... 360
- Kalmia glauca.... 148, 163, 283
  - See Pale Laurel.
- Kearney, T. H., reference.... 175
- Kedzie, R. C., on use of muck for composting.... 294
  - reference.... 175, 292
- Kettle-hole bogs near Vulcan.... 217
- Kettle-hole lake south of Norway.... 219
- Keweenaw Peninsula, lakes and bogs of.... 240
- Kidney-leaved Violet.... 202, 285
- King Fern.... 248, 282
- Kirschbraun, L., peat tests.... 338
- Kleinstuck, C. G., peat fuel made by.... 360
- Koller, T., moors.... 115
  - peat formation.... 126
  - reference.... 175
- Koss, White Pine Forest near.... 189
  - White Pine Forest near, Plate XVIII.... 101
- Kummel, H. B., reference.... 175

L.

- Laberge, Dr., moss litter used for deodorizer by.... 298
- Labrador Tea.... 164, 194, 195, 199, 202, 203, 210, 212, 214, 222, 223, 227, 228, 230–237, 239, 241, 245, 247, 248, 250–252, 256–258, 262–264, 266, 274, 283
- Ladies' Tresses.... 230, 283
- Lake Antoine, early stages of filling shown by.... 219–221
    - Sphagnum bog near.... 221
  - Bulrush.... 130, 139, 196, 197, 201, 202, 210, 211, 218, 220, 234, 238, 243, 245, 282
  - margin at Nathan, Plate XXI.... 101
  - Mary, Spruce-Shrub-Sedge bog near, Plate XXVII.... 101
  - Michigan, islands, floral succession in bogs of.... 159
    - peat formation near, Manistique.... 254
    - plant distribution near, in Menominee county.... 188
  - near Badwater Lake, Plate XXIV.... 101
  - near Menominee river.... 219
  - near Winona Mine.... 241
  - Orion, White Cedar, peat deposit.... 122
  - partly filled.... 229
  - St. Clair, water plants of.... 129
  - Superior, bogs and marshes near.... 186
    - buried peat on shore of.... 243
    - peat formation near shore of at Marquette.... 251
- Lakeland, Dasiphora fruticosa at.... 162
  - marsh land around.... 109
  - sedge marshes, peat deposit near.... 124
  - tamarack swamps near.... 122
- Lakes between Newberry and Grand Marais.... 246, 248
- Lakes around Crystal Falls.... 228
  - deep, near Stager.... 234
  - at Deer Park Life Saving Station.... 248
  - on Keweenaw Peninsula.... 240
  - manner of filling.... 195
  - near Marquette.... 245
  - near Sagola.... 227
  - northern and southern, comparison of filling.... 269
  - near Crystal Falls.... 233
  - in T. 49 N., R. 29, 30 W.... 262

Page
Lance-leaved White Violet..........255, 285
Land Surface, peat deposits classified according to.......... 115
  plant distribution.......... 188
Lane, A. C., cited..........105, 112, 176, 184
Lansing, heath swamps, peat deposits near.......... 124
Large Cranberry..........142, 199, 202, 218, 256, 257, 282
  Toothed Aspen..........197, 281
Larger Blue Flag..........211, 218, 219, 281
Larix laricina, see Tamarack..........109, 140, 149, 284
Late Golden-rod..........219, 282
Lathyrus palustris, see Marsh Pea.
Leavitt, T. H., acknowledgments..........176, 361
Leavitt peat machinery, Plate XXXI..........101, 313, 350
LeConte, J., peat bogs..........110, 176
Ledum Grœnlandicum, see Labrador Tea.
Lemna trisulca.......... 140
Leptorchis Lœselii.......... 143
Lesquereux, L., peat formation..........126, 176
Lesser Bladderwort.......... 216
Lesser Duckweed.......... 206
  Panicled Sedge..........141, 196, 203, 206, 207, 230, 284
Leverett, Frank, acknowledgments.......... 185
  reference..........176, 186, 246
Lexington, Mass., peat fuel made at.......... 313
Lichens..........266, 268
Light, a factor in the growth of plants..........165, 170
Lime acetate, peat coke, by-product.......... 301
Limnodorum tuberosum, see Calopogon.
Limnorchis dilata, see Tall White Bog Orchis.
  hyperborea, see Tall Green Orchis and Tall Leafy Green Orchis.
Lincolnshire, peat formation.......... 126
Linnæa Americana, see Twin-flower.
List of plants..........281–286
Little Hemlock river, lake near.......... 231
  Prickly Sedge..........195, 236, 267, 284
  Traverse Bay, precipitation around.......... 112
Littlefield Lake, peat deposits on marl, at..........117, 123
Liverwort, peat formation.......... 134
Livingston, B. E., reference..........160, 176
Livingston county, Aronia arbutifolia in.......... 163
  lakes, sedge mats in.......... 152
  Spruce, peat deposits in.......... 123
Lobelia Dortmanna..........128, 285
  See Water Lobelia.
Locality, types of, examined in Northern Peninsula.......... 188
Location of Peat beds in Michigan.......... 326
Locomotives, peat coke as fuel for in Russia.......... 341
Loire river, peat bogs along, in France.......... 111
Long Lake.......... 137
Long Sedge.......... 264
Long's Lake, Genesee county.......... 151
Longyear, J. M., cost peat coking plant.......... 304
Lonicera oblongifolia..........159, 283
Low Black Blueberry..........223, 227, 250, 266, 281
Low Blueberry..........234, 236, 237, 245, 250, 251, 255, 258, 262, 264, 266, 281
  Juniper..........265, 285
  Raspberry..........212, 284
Luce county, analyses of peat from.......... 328
Ludington, analyses of peat from.......... 330
Lung diseases, peat smoke beneficial in.......... 333
Lycopodium inundatum, see Bog Club-moss.
Lycopus Americanus..........144, 283
  See Cut-leaved Water Hoar-hound.
Lycopus cummunis.......... 140
  sp., see Bugleweed.
Lyndon township, morainal lake in.......... 116

Page

M.

MacCourt, W. E., reference 177
MacFarlane, T., reference 176
McLeod's Lake, flora of 247
Machinery, peat 312, 344, 346, 352, 354
    Leavitt peat, Plate XXXI 101
    for making peat litter 343, 357
Mackinac Island, Tamarack on 164
McKone, W. J., Geological Survey Board 95
Macleod, River, beaver dams of 168
MacMillan, C., formation of Sphagnum atolls 151, 176
Magellan Sedge 206, 212, 230, 241, 248, 284
Magnesium carbonate, peaty soils 291
Manistique, dams formed by drift-wood on the, described 118, 126
    peat formation among sand dunes near 254–260
    peat studies at 186
Manna-grass 213
Mannhardt and Koch press, peat machine 347
Mansfield, conifer bog near, Plate XIX 101
Mansfield Mine, peat deposit lowered 194
Maple (see Acer spp.) 142, 203, 241
  river swamp 118, 119
Mappe, Ludwig, peat used as deodorizer by 297
Marchantia, in early stages of peat formation 134
Marginal basins 117
  zone, lake 208, 221, 270–274
Market, location of peat deposits in relation to 318
Marl below peat 324
  deposits, Chara 131, 132
Marquette, bogs and marshes near 186
    buried peat near 252
        Fig. 16 101
    forests on north and south hillsides near 262
    lakes near 245
    peat formation near 251, 252, 260
Marsh Arrow-grass 203, 281
  Bellflower 211, 228, 234, 281
  Cinquefoil 141, 143, 196, 197, 206–208, 210–212, 215–218, 220, 224, 225, 228–231, 234, 238, 242, 243, 251, 252, 257, 263
Marsh, defined 109
  Marigold 206, 230
  Pea 219, 283
  St. John's-wort 140, 218, 229, 231, 234, 264, 265, 284, 286
  Shield fern 140, 141, 142, 157, 158, 195, 196, 197, 203, 205–208, 210–213, 220, 228, 230, 231, 282
  Skullcap 211, 216, 284
  societies 265, 266
  White Violet 141, 143, 195, 206, 207, 213, 230, 285
  Willow Herb, see Epilobium palustre.
Marshes, ecological study 183
Martin of Ofenburg, hand machines, peat litter 358
Mary Lake, mature bogs near 236, 237
Mason, F. H., estimates, peat briquettes 356
Massachusetts, peat deposits in 110
Mattings made from peat 308
Mattison Lake, marl, Chara 131
Mattresses, peat litter 298
Mature bog 212, 228, 231, 238, 257
Mature bogs near Mary Lake 236
Maumee Lobe, moraine dam 117
Meadow Sweet 217–219, 224, 233, 236, 238, 245, 252, 255, 283
Mecosta county, peat plant in 360
Melampyrum lineare, see Cow-wheat.
Melton, beaver dams in Canada described by 168
Menominee, plant distribution near 188, 193

Page
Menominee county, plant studies in ... 184
    river, Lake near ... 219
    peat deposit ... 195
    river, pine forests along ... 189
    Sphagnum growth of in ... 275
Mentha Canadensis, see Wild Mint.
Menyanthes trifoliata ... 141, 143, 147, 281
    See Buckbean.
Merryman's Lake ... 203, 204, 210–212
    lake near, Fig. 11 ... 101, 211
Metallurgical processes, peat coke for ... 341
Method of development, classification of peat according to ... 120
Michigan, acres of muck land in ... 105
Michigan, distribution of peat in, Plate XVI, XVII and ... 111
Michigan Peat and Marl Company ... 360
Michigan Peat Company ... 360
Michigan, peat fuel in ... 313
Michigan, Physical features ... 114
Michigan State Board of Agriculture Reports, reference ... 177
Mills, W. M., peat formation at Eagle Lake, Ind ... 128, 177
Mimulus ringens, see Monkey Flower.
Minden township, Sanilac county, peat bogs in ... 360
Mineral matter, peat ... 291, 322
Minnesota, peat bog ... 110
Mitella nuda, see Small Bishop's-cap.
Moisture, condensation of ... 214, 268
Molasses, stock food ... 297
Monkey Flower ... 219, 283
Monotropa uniflora ... 147, 149, 283
    See Indian Pipe.
Montcalm county, Cassandra ... 163
    Chara, marl ... 131
    Spiraea tomentosa ... 164
Montreal, peat litter experiments at ... 298
Moor ... 109
Moors, Schimper ... 115
Morainal lakes ... 116, 117
Moraines ... 190
Morenci, peat bogs near ... 360
Morgan, L. H., reference ... 177
Moss bogs, peat deposit ... 121, 124
Moss ... 158, 199, 207, 208, 215, 256, 266, 268, 276
Mountain Ash ... 232, 250, 264, 281
    See American Mountain Ash.
    Holly ... 147, 223, 234, 236, 245, 248, 250, 258, 266, 283
    Maple ... 230, 274, 283
Mouse-ear Chickweed ... 267, 285
Muck and peat, distinction between ... 108, 289
Muck land, acres of in Michigan ... 105
    soils, growing crops on ... 290
    in agriculture ... 289
    Water holding power of ... 290
Mud Lake ... 122, 145, 151, 158, 159, 166
    heath swamps, peat deposit at ... 124
    sedge mat at ... 139, 152
    Spruce, peat deposit around ... 123
    Vaccinium Pennsylvanicum at ... 162
    Willow swamp, on peat deposit at ... 123
Mud Sedge ... 141, 199, 207, 217, 218, 222, 229, 230, 236, 237, 241, 242, 251, 252, 255, 257, 271, 272
Muller, C., peat cutting machine described ... 346
Munising, peat swamps southeast of ... 276
Muntz and Laine ... 310
Myrica Gale ... 159, 164, 284
Myriophyllum, water plants ... 128, 129, 132
Myrtle-leaved Willow ... 196, 197, 217, 228, 236, 251, 252, 257, 285

Page

N.

Naias flexilis, see Slender Naias.
Naidaceae, water plant 129
Nathan, filled lake near, Plate XXI, XXII and 201, 221
  peat bog, pond near 198
National Peat Fuel Company, Chelsea 359
Naumbergia thyrsiflora, see Tufted Loosestrife.
Negaunee, Beaver dam, Plate XIV and XV 101
Nerved Manna-grass 143, 206, 211, 217, 218, 219, 252, 255, 256, 282
Netherlands, peat fuel in 311
New Brunswick, sphagnum for stable bedding from 296
  England peat fuel in 313
   habitats in 143, 163
  Hampshire, Spiraea tomentosa, habitats in 164
  Jersey, peat beds in 329
  York, peat bogs of 110
   sunshine in 113
Newberry celery soil, analysis of 294
  Great Swamp near 246, 248
  peat studies in vicinity of 186
Newcastle cannel coal, gas 306
Nich-e-waugh Lake, Chara, marl 131, 132
Nightshade 142
Nillson, N. H., ecological factors according to 160
Nitrates, peat in production of 310
Non-conducting packing material 309
North Carolina, peat bogs in 111
North side of hills, woodland 261, 262
Northern and Southern lakes, comparison of filling 269
  Michigan, plants, general distribution of 188
  Peninsula, climbing bogs in 120, 264
   peat bogs, formation, character, distribution 181
   Sphagnum and peat formation 274
  Water Star-wort 256, 284
Northfield township, pond in 151
Norway and Jack Pine forest 192
Norway, lake south of 219
  manufacture and use of peat coke in 304
  peat land 110
  Pine 189, 190, 217, 218, 221, 222, 224, 226, 227, 233, 234, 236, 245, 247–251, 253, 257, 262, 266, 283
Nuphar, water lily 132, 137
Nurserymen, peat packing material for 309
Nymphaea advena 130, 132, 133, 139, 283

O.

Oakland county, lakes of 133
   sedge mats around 152
  peat beds in 326
  White Cedar, on peat deposits of 122
Occurrence of peat 108
Ogdensburg, N. Y., peat gas plant projected at 307
Oil from tar, peat coke 303
Onoclea sensibilis 141, 219, 282
Ontario, manufacture and use of peat briquettes in 313
Ontonagon county, swamp areas in 277
Open mold system, briquetting peat 354
Ophioglossum vulgatum 141
Organic acids, present in muck land 291
Original vegetation, map, Plate XVII 101
Orlando, Fla., peat plant operating at 351
Ortonville, slope bogs near 120
Osmunda cinnamomea 143, 282
  See Cinnamon Fern.
  regalis 140, 143, 282
  See King Fern.

Page
Ostrya, Virginica, see Ironwood.
Oxalis stricta ... 285
"Ox-bow" basins ... 117
Oxford, peat section near ... 166
Oxycoccus macrocarpus ... 146, 147, 149, 282
  See Large Cranberry.
  Oxycoccus ... 146–148, 282
  See Small Cranberry.

P.

Packing material, use of peat litter for ... 309
Pale Corydalis ... 266, 285
  Laurel ... 148, 194, 199, 200, 217, 222, 223, 225, 226–228, 232, 235, 236, 238, 239, 241, 242, 247–250, 256–258, 283
Panicled Cornel ... 142
Panicularia Americana, see Tall Manna-grass.
  fluitans ... 129, 282
  See Floating Manna-grass.
  nervata ... 143, 282
  See Nerved Manna-grass.
Panicum ... 255, 285
Paper pulp, peat ... 280, 307
Paraffin, from peat coke ... 103
Park Lake, peat formation at ... 336
Parmelee, C. W., peat investigations of ... 177, 326, 329, 334
Parsons, A. L., reference ... 377
Pasteboard, peat fiber used in ... 108
Paving blocks from peat ... 310
Pearly Everlasting ... 267
Peat, acre of, tons of fuel in ... 277, 318
  Agricultural uses of ... 289
  lands, area in Michigan ... 289
  as a fertilizer ... 293–295
  as fuel ... 311
  as stock food ... 297
  beds, location and extent in Michigan ... 326
  bog at Nathan ... 198
  bog, Plate XXIX ... 101
  bogs, agricultural possibilities of ... 279
    development and character of ... 183
    formation, character, distribution of ... 181, 183
    Huron Mountains ... 260
  buried, Lake Superior shore ... 243
    near Marquette ... 252
  carrying from bog to factory ... 358
  coke ... 278, 299–305, 340–342
  compared with other fuels ... 333
  composition of ... 327
  cut, machinery for making ... 344
  cutter, Fig. 19 ... 101
  definition of ... 107
  deodorizer and disinfectant ... 297, 298
  deposit, Bentley's camp, Plate XXVIII ... 101, 264
    surface plants in relation to ... 166, 187
  deposits, area and depth, necessity of determining ... 318
    classified ... 115
    commercial value of ... 318
    depth, degree of decomposition, extent ... 183, 187
    relation of to plants on the surface ... 128
  description of ... 108
  destructive distillation of ... 299
  disinfectant, farm use of ... 296, 297
  distribution and abundance of ... 276
  dye ... 310
  electrical energy from ... 280, 31

Page

- Peat, factories, Michigan 359
  - factory, plans and section, Fig. 20 101
  - formation 111, 130, 134, 252, 269, 274
    - ecology of, etc 105, 251
    - near Manistique 254
    - species of plants important in 274
  - fuel, heating power of 332, 334
    - machinery for preparation of 343
    - Plate XXX 101
  - gas 280, 305–307
  - geographical distribution of 110
  - litter, fertilizer for agricultural crops 298
- Peat litter, machinery for preparation of 343, 357
  - methods of work on 187
  - miscellaneous uses of 289
- "Peat mosses" 159
- Peat mull 357
  - muskeg, James Bay 111
  - occurrence of 108
  - paper pulp from 280, 307
  - physical condition of, factors determining 319
  - plant, estimate of cost of 352
  - prospects, Michigan 359
  - relation of to bottom 323
    - to water plants and sedge 152
  - samplers, Fig. 18 101
  - succession of plants upon mat 158
  - tests 338
  - use in hospitals 298
  - water content of 161, 336, 338
  - woven fabrics from 308
- Peltandra Virginica 139, 141
- Pembina, beaver dams 168
- Pennington, L. H., reference 177
- Pennsylvania Sedge 255, 284
- Percy, John, Mannhardt and Koch press 347
- Pere Marquette R. R., bogs along 154
- Perry, heath swamps, peat deposits near 124
- Peshekeme river, climbing bogs near 264
  - swamps near 262
- Pettee, E. E., reference 177
- Pettit, R. H., beaver meadow 101
- Pennsylvania, peat bogs in 110
- Phenolates, from peat coke 303
- Philadelphia Flea-bane 219, 282
- Phleum pratense, see Timothy.
- Phragmites phragmites 129, 132, 282
  - See Tall Reed-grass.
- Physical condition of peat, factors controlling 319
  - features, Michigan 114
- Picea brevifolia 142, 146, 149, 284
  - See Black Spruce.
  - Canadensis, see White Spruce.
  - Mariana, see Spruce and Black Spruce.
- Pickerel-Weed 130, 139, 195, 283
- Pigweed 286
- Pieters, A. J., reference 129, 177
- Pilgrim Paper Co., peat paper 308
- Pin Cherry 189, 197, 282
  - See Wild Red Cherry.
- Pine 190, 247, 252, 255, 261, 265
  - "Island" Lake Antoine, Plate XXIII 101, 220
  - Lake, barrier-formed lake 117
  - lands 188
  - river, dam 118
    - swamp area near 119

Page

Pinus divaricata, see Jack Pine.
  resinosa, see Norway Pine.
  strobus, see White Pine.
Pipe-wort.......... 242, 283
Pitcher plant.......... 143, 199–203, 207, 217, 218, 222, 225, 226, 228–230, 232, 234–239, 241, 242, 247–249, 263, 264, 283
Plant growth, cycle of.......... 166
  societies.......... 184, 186, 265
    in relation to soil and topography.......... 190
  tissues, breaking up of.......... 337
Plants, distribution of.......... 184
  general distribution, northern Michigan.......... 188
  list of.......... 281–286
  occurrence, range and distribution of.......... 184
  peat formation.......... 172, 187
  precipitation of mineral matter by, in peat.......... 322
  relation of to peat deposits.......... 128
  succession of upon peat after grounding of sedge mat.......... 158
  surface, no indication of character of peat deposit.......... 166
Poa compressa, see Wire grass.
  pratense, see Blue grass.
Podostemon, water plant.......... 128
Poison Sumach.......... 142, 144, 157
Poles, preservative for.......... 303
Polygala paucifiora, see Fringed Polygala.
Polygonum Conolvulus, see Black Bindweed.
  emersum, see Swamp Persicaria.
  Hartwrightii, see Hartwright's Persicara.
  hydropiper, see Common Smart-weed.
Polypodium vulgare, see Common Polypody.
Polytrichum.......... 124, 149, 283
  See Hair-cap moss.
Pond Lily zone.......... 269
Pond, R. H., reference.......... 177
    water plant growth.......... 132
Pondweed.......... 129, 215, 216, 220, 224, 225, 234, 238, 241, 247, 248, 251, 256, 269, 283
Pontederia cordata.......... 130, 139, 283
  See Pickerel Weed.
Poplars.......... 147, 150, 156, 166, 189, 190, 192, 197, 215, 233, 234, 238, 252
Populus balsamifera, see Balsam Poplar.
  tremuloides.......... 149, 150, 156, 281
  See Aspen, American Aspen.
Porcupine Sedge.......... 195, 216, 238, 284
Portage Canal, section of buried peat near, Fig. 15.......... 101
Posts, tar from peat preservative for.......... 303
Potamogeton.......... 129, 131–134, 137, 139, 208, 283
  See Pondweeds.
Potamogeton natans, see Common Floating Pondweed.
Potato, amount of water required growing in peat.......... 161
Potentilla Monspeliensis.......... 144, 285
Prairie Willow.......... 236, 245
Precipitation of mineral matter by plants.......... 322
    in Michigan.......... 112
Preparation, cost of, peat fuel.......... 342
    methods of peat.......... 336
Preservatives of wood.......... 303
Presque Isle Park, peat formation near.......... 251
Pressed peat, machines for making.......... 346
Pressing peat, effect on heating power of.......... 335
Pressure, as means of extracting water from peat.......... 337
Prickly Sedge.......... 142, 207, 225, 230, 242
Production, cost of.......... 352
Proserpinaca, water plant.......... 128
Prospecting methods, peat.......... 315
    necessity of careful.......... 277
Prospects, peat, Michigan.......... 359

Page
Prunus Pennsylvanica, see Wild Red and Pin Cherry.
  pumila, see Dwarf Sand Cherry.
  Virginica, see Choke Cherry.
Pteridiuma quilinum 150, 281
  See Common Brake.
Purple-leaved Willow-herb 231, 267, 286
Purple-stem Aster 144
Purplish Meadow-Rue 144, 219, 283
Pursh's Buttercup 216, 282
Pyrola uliginosa, see Bog Wintergreen.

Q.

Quercus coccinea, see Scarlet Oak.
  macrocarpa 156
  platanoides 156
  rubra 156, 283
  See Red Oak.
Quillwort 265, 286

R.

Railroad ties, preservatives 303
Railroads, peat deposits 154
Rain wash, flooding of bogs by 321
Raising of peat deposit 138
Ranunculus 128
  Pennsylvanicus, see Bristly Crowfoot.
  Purshii, see Pursh's Buttercup.
Razoumofskya pusilla, see Small Mistletoe.
Reclamation of beaver pond 264
  swamp land 292
Red Cedar 151
  Cherry (see Prunes) 189
  clover 267, 285
  Maple 142, 147, 156, 166, 192, 193, 241, 261, 262, 266, 283
  Oak 156, 261, 283
  Osier Dogwood 142, 144, 195, 211, 212, 224, 283
  Raspberry 206, 230, 284
  Top Grass 267, 286
Red-berried Elder 266, 285
Redkino, peat coke made at 302, 304
Reed grass, water plant 129, 196, 245
Reed, H. S., reference 177
  water plants 129
Reindeer Lichen 200, 212, 213, 230, 232, 258, 264, 267, 275
Rennie, J., peat formation 125
Reuss, Paul, hand machines, peat litter 358
Rhamnus alnifolia, see Buckthorn 281
Rhizomes 157
Rhus Vernix 142, 144, 147, 157
Ribes prostratum, see field Currant.
Ries, chemical composition of peat 108
  H., peat deposits of New York 110, 127, 137
  reference 177
River-bank Sedge 195, 211, 212, 218–220, 222, 238, 284
River-flooded lake 231
Riverdale, White Cedar, peat deposit 122
Rock Elm 188, 282
Rock island, peat covered 264
  lake 151
  tarn, peat formation in 116, 133, 136
  Panic-grass 285
  ridge type, forest 189
  surface, peat beds on 215
Rockwell, F. C., coking peat 357
Roofing paper made from peat 309

Page
Roripa Americana, water plant 128
palustris, see Yellow Water-cress.
Rosa Carolina 142, 144, 157
Roscommon county, plants in 162, 163, 164
lakes, sedge mats 152
Sphagnum 167
Rough Cinquefoil 144, 267, 285
Hair-grass 264
Round-leaved Sundew 206, 218, 222, 225, 229, 230, 234, 264, 284
Rowe, W. A., reference 292
Rubus Americanus, see Low Raspberry, Dwarf Raspberry.
nigrobaccus, see Tall Blackberry.
strigosus 144, 147, 284
See Red Raspberry.
Rugs made from peat 308
Rumex acetosella, see Sheep Sorrel.
Brittanica 143, 282
Runkel Lake, bog near 231
Rush 255, 256, 284
Aster 140
marshes, peat deposit 121, 124
Russell, I. C., acknowledgments 184
peat bog studies with 183
reference 177
surface geology 188
Russia, peat briquettes 339
coke 341
fuel 105, 311
land 110

S.

Saginaw Bay, east side, ponds near 117
Lake Bulrush 130
marshes 109, 134
peat bog studies 183
County, marsh land in 109
"prairies" 124
river, dam across 118
Sagittaria, water plant 129
latifolia, see Broad-leaved Arrow-head.
Sagola, Lakes near 227
St. Clair county, peat analyses 328
river, delta 120
sedge marsh 124
St. Louis, moraine dam 117
Salix 145, 162
Bebbiana 144, 285
See Bebb's Willow.
candida 164
lucida, see Shining Willow.
myrtilloides 164, 285
See Myrtle-leaved Willow.
nigra 156
sericea, see Silky Willow.
Salts, mineral, muck land 291
Sambucus pubens, see Red-berried Elder.
Sampler for peat prospecting, Robt. Hunt & Co. 317
Sampling final, peat deposits 316
other purposes than fuel 319
San Joaquin, "tule" lands along the 110
Sand below peat 324
dunes, peat examination among 188
ponds, Fig. 17 101
Sand-plain bogs 237
Sand plains, peat examination on 188

Page
Sandy loam 161
moraines, peat examination among 188
soil water 161
Sanilac county, peat analyses 330, 331
peat bogs 360
Sarracenia 143, 146, 149
purpurea 143, 149, 283
See Pitcher plant.
Sartwell's Sedge 141, 203, 211, 284
Sault Ste. Marie, peat swamps west of 276
Saxifraga Pennsylvanica, see Swamp Saxifrage.
Saxony, compressed peat made in 347
Scandinavia, peat fuel in 311
Scarlet Oak 189, 192, 207, 233, 283
Scheuchzeria 218, 235–237, 242, 257, 284
palustris 145, 149, 284
Schimper, A. F. W., plant geography 115
reference 178
xerophytes 160
Schlikeysen, C., peat machinery of 312, 347
Schonomen dryer 353
Schroeter, C., reference 175
Scirpus Americana, Water plant 133
atrovirens, see Dark-green Bulrush.
cyperinus, see Wool-grass.
lacustris, see Lake Bulrush 130–133, 282
subterminalis, see Water Club-rush.
Scotland, mountain bogs, formation of 125
peat bogs 111
Scott, B. W., peat formation 127
reference 178
Scutellaria galericulata, see Marsh Skull-cap.
Seared briquettes manufactured from peat 340
Section of peat 201, 225, 239, 244, 252
Sphagnum island, Vestaburg 166
peat 157
Sedge 208, 216, 227, 228, 230, 234, 238, 243, 250, 252, 255–258, 271, 274, 275
Sedge and Cat-tail zone 269
bog near Clara Lake 233
islands, near Manistique 256
marsh, Plate XX 101
marshes and bogs, peat deposits 121, 124, 145, 203, 207, 229, 236, 245, 247, 251
mat 137–140, 147, 152, 153, 158, 159, 206, 208, 211, 219, 220, 221, 247, 271
succession of plants upon peat after grounding of 158
Sedge-Sweet Gale Zone 230
Sedge, relation to peat formation 152
Sedge zone 229, 270, 271, 275
Seed plants in water 128
succession of 133
Seeds, birds transporting 266
dispersal of 165
Selwid and Lange, drying chambers invented by 353
Sensitive Fern 141, 219, 282
Seville township, Gratiot county, stony deposits by moss 321
Shade, growth of plants in 165
Shading of plants 130
Shaler, N. S., area of peat formation 110
bog, section of, Fig. 2 101, 127
climbing bog 120
filling of lakes 137
peat formation 114, 126, 178, 313
peat fuel 178
Shallow depressions, formation of peat in 131
water, plants of 141
Shannon river, peat bog on 111
Sheathed Cotton-grass 149, 199–201, 214, 222, 223, 228, 232, 241, 248

Page

- Sheathing paper from peat 309
- Sheep Sorrel 214, 267, 284, 286
- Sheet paper 308
- Sherzer, W. H., reference 178
- Shining Willows 211, 285
- Shore wash in lakes, effect on peat 322
- Showy Ladies' Slipper 203, 210, 212, 213, 283
- Shrub zone 145, 146, 160, 196
- Shrub-Sphagnum zone 218, 221, 222, 242, 263, 272
- Shrubby Cinquefoil 144, 212, 282
- Shrubs 157, 165, 275
- Sibbaldiopsis tridentata, see Three-toothed Cinquefoil.
- Silica as impurity in peat 323
- Silicious bottoms, peat formation on 125
- Silky Cornel 212
  - Willow 218, 285
- Silver Lake, Yellow Pond Lily absent from 134
- Silver Sedge 150
- Sister Lakes, tarns 116
- Skunk Cabbage 143, 144
- Slane (Slayne) Plate XXIX 101, 343
- Slender Cotton-grass 207, 212, 236, 237, 242, 248, 282
  - Naias 248, 283
  - Rush 219, 267, 284
  - Sedge 141, 196, 197, 207, 210, 212, 217–220, 225, 226, 228, 229, 233, 234, 236, 238, 242, 243, 245, 248, 249, 251, 252, 257, 263, 265, 269, 271–273, 284
- Small Bedstraw 142, 216, 265, 285
  - Bishop's Cap 206, 207, 213, 230, 281
  - Bur-reed 255, 282
  - Cranberry 199, 202, 203, 206, 207, 212, 217, 218, 222, 223, 225, 228, 230, 232, 234–239, 241, 242, 257, 258, 264, 282
  - Goose-grass 206, 282
  - Mistletoe 199, 232, 283
  - St. John's-wort 266
  - Spikerush 243
- Smaller Bladderwort 206, 281
- Smaller Bur-Marigold 231, 282
- Smokeless character of peat fuel 335
- Smooth Goldenrod 264
- Smyth, B. B., reference 178
- Sneeze-weed 219, 284
- Soft-leaved Sedge 142, 202, 206, 212, 284
- Soft Maple 193
  - Rush 218, 284
- Soil in relation to plant societies 190
  - peat formation 170
- Solanum Dulcamara 142
- Solidago Canadensis 144
  - serotina, see Late Golden-rod.
- Sorbus Americana, see Mountain Ash and American Mountain Ash.
- Sourness, of muck land 291
- South America, peat in 110
- South side of hills, forests on, in Huron Mountains 261, 262
- Southern and Northern lakes, comparison of filling 269
- Southern bogs 274
  - Peninsula, aquatic plants of 269
    - plants in 219
- Sparganium 129, 282
  - eurycarpum, water plant 129
  - minimum, see Smaller Bur-reed.
  - simplex angustifolium, see Submerged Bur-reed.
- Spathyema foetida 143, 144
- Species, important in peat formation 274
  - list of scientific and common names 281

Page
Sphagnum ... 143-284
    atolls, formation of in Minn. ... 151
    bog near Lake Antoinè ... 221
    island, section of ... 166, 236
    moss bogs ... 124, 126, 166
    in relation to peat formation ... 127, 134, 135, 157
    swamps ... 163
    Vestaburg, Plate XIII ... 101
    zone ... 164
Sphagnum-Cassandra zone ... 147, 149
Sphagnum-Cassandra-Andromeda zones ... 220
Sphagnum-Heath Association ... 232
Sphagnum-Shrub zone ... 226
Spike-rush ... 243, 265, 271, 286
Spinulose Fern ... 267
Spiraea salicifolia, see Meadow Sweet.
    tomentosa ... 164
Spotted Cowbane ... 282
    Touch-me-not ... 140, 143
Spring bog near Camp Lake ... 230
    bogs, peat ... 321
Springs ... 231
Spruce ... 142, 145, 149, 166, 169, 193-195, 202, 206, 211, 220, 226, 228, 230, 232, 234, 237, 241, 246, 247, 250, 251, 261, 262, 266, 273
    See also different species.
Spruce bog at Balsam ... 232, 233
Spruce Pine ... 261
    swamps, peat deposit ... 121, 123
Spruce-Shrub-Sedge bog near Lake Mary, Plate XXVII ... 101
Spruce-Tamarack Association ... 250
Spruce-Tamarack-Sphagnum Association ... 203
Spurred Gentian ... 212, 282
Stable and Barn-yard litter ... 295
Stabler process, drying peat ... 353
Stachys aspera, see Hedge Nettle.
Stager, deep lakes near ... 234
Star-flower ... 206, 212, 284
Stauber process, drying peat ... 353
Steironema ciliatum, see Fringed Loosestrife.
Stemless Ladies' Slipper ... 147, 239, 283
Stock food, peat ... 297
Strand-flora ... 243
Streams, flooding by, peat deposits injured by ... 321
    peat examination of along ... 188
Structure, peat deposits ... 95
Stuart's Lake ... 247
Stutzke Brothers, peat presses ... 350
Submerged Bur-reed ... 241, 282
Succession of plants after grounding of mat ... 158
    seed plants ... 133
Sugar Maple ... 240
Sulphate of iron, peat ... 291
Sulphur, peat ... 335
Summerfield township, peat bogs ... 360
Sundew ... 199
Sunshine, Michigan ... 113
Surface growth, peat, character of ... 320
    plants, peat deposit ... 166
    vegetation and peat ... 96
    classification of peat deposits ... 121
Swamp area ... 119
    Blueberry ... 147, 148
    defined ... 109
    distribution, map of, Plates XVI and XVII ... 101
    Honeysuckle ... 159, 194, 195, 202, 212, 283
    Horsetail ... 142, 216, 265, 285

Page

Swamp inland dune region........ 116
  land, areas of........ 105
    reclamation of........ 292
    area in Michigan........ 289
  Loosestrife........130, 139, 204–208, 270, 273, 283
  Milkweed........144, 211, 219, 283
  Persicaria........196, 220, 224, 283
  Rose........142, 144
  Saxifrage........203, 206, 213, 230, 284
  Thistle........211, 284
  Valerian........202, 213, 285
  White Oak........ 156
    Violet, see Marsh Violet.
  Wild Rose........157, 263
Swamp-conifer border........ 222
Swamps, types of........ 262
Swampy areas, examination of........ 188
Sweden, pasteboard from peat made in........ 308
  peat briquettes........ 339
    drainage........ 320
    fuel........ 105
    gas........280, 305
    land........ 110
Sweet Fern........163, 189, 197, 223, 227, 233, 237, 282
  Flag........224, 243, 284
  Gale........159, 195, 196, 201, 202, 224, 227, 230, 231, 234, 243, 245, 248, 251, 255, 257, 263–266, 269, 274, 284
  White Violet........202, 265, 286
  Wild Violet........ 285
Sweet-scented Water Lily........226, 285

T.

Tall Blackberry........233, 236, 264, 281
  Cotton-grass........142, 203, 207, 217, 218, 226, 235, 256, 282
  Green Orchis........207, 212, 283
  Leafy Green Orchis........141, 230, 283
  Manna-grass........233, 282
  Reed Grass........196, 282
  White Bog Orchis........228, 230, 283
Tamarack......109, 130, 140–150, 156, 159, 164–166, 169, 189, 191–197, 199, 201, 264, 266, 284
Tamarack-Alder association........ 245
Tamarack-Black Spruce zone........ 235
Tamarack-Sedge association........ 203
Tamarack-Spruce-Cedar Swamp........204, 212, 215, 219, 223, 227, 228, 231
Tamarack swamps........121, 122, 163
Tannic acid, in muck land........ 291
Tar covering, peat briquettes........ 339
  peat coke by-products........301, 303, 305
Tarns........ 116
Tarr, R. S., peat formation........ 127
Temperature, Michigan........112, 113
Terrace bogs, peat........ 321
Tests, peat........ 338
Tetragonanthus deflexus, see Spurred Gentian.
Texture, peat deposits........ 325
Thalictrum purpurascens........144, 283
  See Purplish Meadow-Rue.
Thanlaw, J. G., water in peat........ 336
Three Rivers, peat bogs near........ 360
Three-leaved Sedge........ 284
  Solomon's Seal..143, 200, 202, 210, 213, 214, 223, 228, 230, 232, 235, 239, 241, 248, 284
Three-seeded Sedge........142, 150, 200, 206, 214, 232, 236, 241, 248, 258, 267
Three-toothed Cinquefoil........245, 282
Throat diseases, peat fuel beneficial for........ 333

Page
Thuja occidentalis, see Arbor Vitae, Cedar, White Cedar.
Tiles, peat paper...... 308
Tilia Americana, see Basswood.
Till below peat...... 323
    plain...... 119
Timber land, forestry...... 184
Timothy...... 286
Tissues, plant, breaking up of...... 337
Tobico Lake, barrier formed lake...... 117
Tools for prospecting peat deposits...... 316
Topography in relation to plant societies...... 190
    plant distribution...... 188
Torch Lake, barrier formed...... 117
Touch-me-not...... 231, 285
Towar, J. D., swamp lands in Michigan...... 178, 289, 292
Trailing Arbutus...... 223, 227, 237, 245, 250, 251, 255, 258, 266, 281
Transeau, E. N., reference...... 178
Transition type, mature bog societies...... 257
Transportation, peat deposits...... 318
Traskatis, G., peat presses...... 350
Triadeum Virginianum...... 140, 284, 286
    See Marsh St. John's-wort.
Trientalis Americana, see Starflower.
Trifolium pratense, see Red Clover.
    repens, see White Clover.
Triglochin palustris, see Marsh Arrow-grass.
Trout Lake Junction, beaver dams...... 169
    bogs...... 249
    Junction, peat studies...... 186
Tsuga Canadensis, see Hemlock.
Tufted Loosestrife...... 206, 283
Tule lands, California...... 110
Tunnel type drying chambers, peat...... 353
Turf-building type, Sedges...... 271
Tuscola county, Dasiphora fruticosa...... 162
    Gaylussacia resinosa...... 162
    marsh land...... 109
    "prairie"...... 124
Tussock Sedge...... 195, 199, 205, 210, 218, 231, 234, 238, 271, 272, 284
Twig-rush...... 201
Twin Falls, bogs near...... 226
Twin-flower...... 195, 202, 206, 210, 212, 213, 227, 230, 236, 251, 285
Two-storied White Pine and hardwood forest...... 192
Type of filling...... 270
Types of locality examined, peat...... 188
    swamps and bogs...... 262
Typha, latifolia...... 129 to 145, 147, 148, 150, 151, 152, 158, 168
    See Cattail.

U.

Ulmic acid, muck land...... 291
Ulmus Americana...... 142, 147, 156, 282
    See White Elm.
    racemosa, see Rock Elm.
Umbelliferæ...... 128
Unifolium Canadense...... 143, 150, 283
    See Wild-Lily-of-the-Valley.
U. S. Consular reports...... 179
    Department of Agriculture, Bureau of Soils...... 178
    swamp land...... 111
Upper Peninsula, map of original vegetation, Plate XVII...... 101
Upright Yellow Wood Sorrel...... 219, 285
Utilization of peat on a large scale, reference...... 179

Page

Utricularia, water plants....128, 129, 132, 133, 137
  cornuta, see Horned Bladderwort.
  intermedia....129, 140, 281
  See Flat-leaved Bladderwort.
  minor, see Smaller Bladderwort.
  purpurea, water plant.... 129
  vulgaris....129, 132, 281
  See Greater Bladderwort.

V.

Vaccinium Canadense....148, 162, 281
  See Canada Blueberry.
  corymbosum....123, 147–149, 163
  nigrum, see Low Black Blueberry.
  Pennsylvanicum....148, 162, 281
  See Low Blueberry.
Vagnera trifolia....143, 147, 284
  See Three-leaved Solomon's Seal.
Valeriana uliginosa, see Swamp Valerian.
Valley bog near Granite Bluff.... 223
Valley bogs.... 193
  bottom.... 189
Value, commercial, peat deposits.... 318
Van Buren Peat Company.... 360
Vassar, moraine dam.... 117
Vegetable matter, agents of decomposition.... 106
  chemical composition.... 105
Vegetables, peat packing for.... 309
Vegetation, character of.... 96
  original, map of, Plate XVII.... 101
Verbena hastata....144, 285
  See Blue Vervain.
Vestaburg, heath swamp, peat deposit.... 124
  Plate XIII, Peat.... 101
  Sphagnum island, section.... 166
Viburnum cassinoides, see White-rod.
Vicksburg, Wolverine Peat Company.... 360
Viola alsophila....140, 141, 143
  blanda, see Sweet Wild Violet.
  Labradorcia, see Dog Violet.
  lanceolata, see Lance-leaved Violet.
  Le Conteana, see Marsh Violet.
  renifolia, see Kidney-leaved Violet.
Virginia Cotton-grass....149, 218, 222, 226, 232, 237, 241, 248, 249, 264, 282
  Chain-fern.... 147
  peat bogs.... 110
Vulcan, bogs near.... 217

W.

Waldsteinia fragarioides, see Barren Strawberry.
Warrington, R., reference....161, 179
Wash, shore, in lakes.... 322
Washtenaw county, peat analyses.... 328
  Aronia arbutifolia.... 163
  lakes, sedge mats.... 152
  Spruce, peat deposit.... 123
Water Arum.... 206
  Club-rush....199, 282
  content....290, 336–338
  Lily family.... 129
  Lobelia....265, 285
  persicaria.... 196
  plantain, ... 129
  plants, relation to peat....129, 152

Page
Water Sedge........196, 284
  Shield........197, 237, 246, 285
  Starwort........206, 284
Water-milfoil family........128, 211
Waterbury, L. E., sink hole on Grand Trunk R. R........154
  peat analyses........332
Wayne county, beaver dams........167
Webster township, sedge mat........139
Weight of peat deposits........324
Weitzmann, K., machinery for making condensed peat........346, 349
Weld, L. G., reference........179
Welland county, Ontario, moss litter........298
West Branch, swamp........109
Wexford county, Andromeda Polifolia........164
  Ilicìodes mucronata........163
  lakes, sedge mats........152
  White Cedar, peat deposit........122
Wheeler, W. H., Lincolnshire peat formation........126
  reference........179
White Ash........147, 224
  Beaked-Rush........199, 222, 225, 237, 242, 264
  Birch........189, 190, 192, 193, 196, 218, 252, 258, 261, 262, 264, 266, 281
  Cedar........122, 189, 193, 195, 206, 210, 212, 243, 247, 262–264, 281, 282
    See Cedar.
  Clover........267, 285
  Elm........142, 156, 188, 189, 192, 196, 261, 282
  Pine........190–192, 195, 202, 218, 221, 222, 224, 226, 227, 234, 241, 242, 247, 249, 250, 257, 261, 262, 264, 266, 283
    forest near Koss, Plate XVIII........101
    Type........192
  Pond Lily........130, 133, 195, 197, 220, 225, 234, 237, 248, 283
  Spruce........188–192, 261, 284
Withe-rod........247–250, 256–258, 285
Whitewater, Wisconsin, seared briquettes made........340
Whitford, H. N., flora succession of........159
  on swamp societies........128
  on xerophytes........160
  reference........179
Whitmore Lake........116, 122, 133, 136, 145, 151
Wigan cannel coal, gas........306
Wild Calla Lily........206, 213, 216, 229, 230, 241, 251, 263
  Lily-of-the-Valley........206, 207, 213, 250, 267, 283
  Mint........219, 234, 283
  Oat-grass........266, 267, 285
  Potato........142
  Red Cherry........197, 214, 266, 282, 285
    Raspberry........144
  Sarsaparilla........150, 206, 207
  Strawberry........267
Willow........147, 150, 159, 164, 166, 168, 195, 197, 210, 211, 212, 215, 216, 218–220, 224, 233, 243
  swamp, peat deposit........121, 123
Winchell, A., climate of Michigan........112
  peat formation........127, 179
Wind, peat formation, effect on........172
Winged Cudweed........267
Winona mine, bogs and lake near........240, 241
Winterberry........147, 224, 248, 256, 266, 285
Wintergreen........212, 213, 223, 227, 239, 245, 250, 251, 258, 266, 285
Wire-grass........266, 285
Wisconsin, peat bog........110
Wisconsin, sunshine........113
Wisner township, marsh land........109
"Witches' brooms"........199, 232
Wolverine Peat Company........360
Wood alcohol, peat coke by-product........301, 303

Page
Wood as fuel 278
 preservatives of 303
Wood-rush 285
Woodwardia Virginica 147, 150
Woody plants, Tamarack zone 142
Wool-grass 218, 219, 228, 236, 248, 252, 255, 256, 265, 285
Woven fabrics from peat 308

X.

Xerophytes 160, 164
Xerophytic adaptations 161, 214, 237

Y.

Yellow Birch 156, 188–193, 196, 240–242, 261, 274, 281
 Pond Lily 130, 132–134, 140, 167, 195, 197, 199, 211, 212, 218, 220, 221, 224–230, 233–235, 237, 238, 241, 243, 245–248, 251, 265, 283
 Sedge 212, 284
 Watercress 219, 265, 285, 286
Ypsilanti, Huron river "cut off" at 118

Z.

Ziegler, peat coke 300
Zizania aquatica, water plant 129
Zschœrner process, peat paper 307
Zwingenberger, O., Ziegler peat coke 301, 303